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A COLLEGE PERSONNEL SERVICE

BY CLARENCE E. BULLINGER

Associate Professor of Industrial Engineering, The Pennsylvania State College

The question of college personnel service has been studied for some time by the School of Engineering of the Pennsylvania State College at several industrial conferences and in a committee of representatives of industry and members of the faculty.

Last spring, a personnel record card was adopted and the procedure agreed upon for carrying on the service.

The committee on the Teaching of Industrial Relations of the Summer School for Engineering Teachers, held at Purdue University during June and July, 1929, made a report which included recommendations for College Personnel Service.

These recommendations reflect quite clearly the basis upon which such a service was established by the School of Engineering, so they are repeated here.

"The type of service depends upon the individual school. It should, in general, include the following:

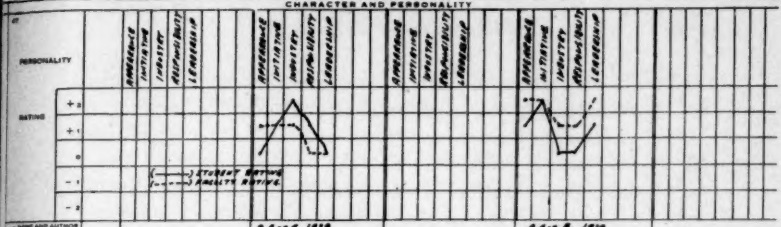
I. The personnel record.
   - *a.* Family history.
   - *b.* Physical condition.
   - *c.* Scholarship.
   - *d.* Extra-curricular activities.
   - *e.* Work and business experience.
   - *f.* Personality and character development.
   - *g.* Placement data.

II. The understanding that the teacher of engineering is vital to the functioning of this service and is, in the last analysis, the personnel officer.

III. Provision for some person to act as a co-ordinator of this service.

| | | |

CHARACTER AND PERSONALITY



PLACEMENT DATA

ADVISER AND PC COMMENTS				
MENTAL TEST	98 CAMP INITIAL 110 TTAC.			
APTITUDE TEST				
VOCATIONAL INTEREST TEST				
HOBBIES	ATHLETICS READING BOY	MAKING THINGS ATHLETICS	ATHLETICS MAKING THINGS	ATHLETICS HANDLING MEN/ A.E. SUBJECTS
STUDIES NATURALLY STRONG IN	MATHEMATICS SHOP	MATHEMATICS SHOP	MECHANICS ARITHMETIC	
STUDIES NATURALLY WEAK IN	LANGUAGE ENGLISH	ENGLISH	POWER LABORATORY	POWER LABORATORY
HAS SPECIAL ABILITY IN	MATHEMATICS	MOTOR HOBBIES	DECORATING	DECORATING-PERSONAL

SUIT FITTED FOR

RESEARCH	( )	SUPERVISION, PLANT	(✓)	SALES-COMMERCIAL	( )	FIELD WORK	( )	DRAFTSMAN	( )
DESIGN	( )	MANAGEMENT, MEN	(✓)	CONSTRUCTION	( )	TEACHING	( )	OTHERS	( )

MISCELLANEOUS

IV. The collection of information concerning each student which may be used for personality development, vocational guidance, placement or other personnel service.

V. The interpretation of the personnel record to the student as an aid in his development."

The record card is reproduced in Figs. 1 and 2. This card is to be folded along the dotted line so that the portion shown by Fig. 1 will be on the inside and the portion shown by Fig. 2 will be on the outside.

It will be noticed that the record card is divided into the seven sections as noted above for the contents of the personnel record.

A description of the various items on this card is not necessary since they are self-explanatory. It should be pointed out that information for any item will be shown in a horizonal direction while information occurring in any given year will appear in the vertical column for that year.

The section on "Scholarship" which includes items 17 to 29 is so arranged that it will indicate the position of the student as regards graduation requirements and will also show his scholastic rating in terms of an average. This section is made, in this case, to conform to the grading system of the college.

It will be noticed that for item 47 there has not been listed any traits of personality. It is quite possible that the rating scale used to gather information for this section may be changed from year to year which might require a change in the traits used. A rubber stamp is to be used to print both the names of the traits and the name and author of the rating scale.

Whenever a space for any item becomes filled and there is still further information to be added, the information is recorded in the "Miscellaneous" section and the corresponding line number is entered where the information properly belongs.

The record card has two uses. The first use is as a record

of the student as he goes through college. The second use is as a file for letters or other papers which may pertain to the student.

The organization for carrying into effect this service is the already existing organization of the school together with a Personnel Secretary whose duties are similar to those laid down in the third section of the report quoted above.

The work of collecting the various items of information is taken care of by Class Advisers or Scheduling Officers. Others who contribute information are members of the Faculty, Heads of Departments and the College Physician.

It is felt that the service as outlined above is simple in application and at the same time comprehensive in its scope. If further particulars are wanted the writer will be glad to furnish them.

SOME NOTES ON AERONAUTICAL ENGINEERING EDUCATION *

BY ALEXANDER KLEMIN

Professor of Aeronautical Engineering, Daniel Guggenheim School of Aeronautics, New York University

Aeronautical engineering embraces not only the design and construction of aircraft and aircraft engines, but also the design of airports and airways, the technical operation of aircraft and a number of other activities. It may in the near future include almost as many subdivisions as electrical engineering. In the following brief paper it is proposed to restrict attention to the more technical aspects of this profession.

Fundamentals

In the pioneer stages of aircraft construction, when purely experimental methods prevailed, successful machines were produced by men of very moderate technical attainments. With the development of the art and the accumulation of scientific theory and data, a better technical foundation for the designer has become essential, and the University type of instruction is now the logical and perhaps the best avenue of approach to aeronautical engineering.

In other branches of engineering, particularly mechanical engineering, instinct and common sense are in many respects a sufficient guide. The properties of the lever and the wheel are part of the common knowledge of mankind.

Flying and the flying machine are not matter of instinct as yet. Aircraft design is to a large extent an application of mathematics and specialized physics, superimposed on the general work of the mechanical or the civil engineer.

* Presented at the 37th annual meeting of the Society, Ohio State University, June 19–22, 1929.

Owing to the somewhat romantic character of aviation, thousands of young men are intensely eager to enter on the profession of aeronautical engineering, and are prone to think that a knowledge of flying and familiarity with aircraft types of the day are a sufficient introduction to the profession.

It cannot be too strongly insisted that this view is erroneous, and that a sound basic education is essential.

Early specialization will produce narrow and unprogressive men.

Since, as stated above, aircraft design is a matter of mathematics and physics coupled with mechanical engineering (and of course of flying and shop experience) the aeronautical engineer must submit to an even more vigorous discipline than engineers in other lines of work.

The usual mathematics covered by engineering students should be extended as far as possible, and should include differential equations.

In physics, electricity and optics are subjects on which no special emphasis need be laid. But mechanics comprising statics and dynamics are all important. The dynamics of the airplane are a splendid application of plane and rigid dynamics. The airplane is undoubtedly the most refined structure of the day, so that it is impossible for an aeronautical student to learn too much of statics. Vibration is a problem which is always bothering the aircraft designer, and the problem of noise in the airplane is far from being solved, so that a fundamental knowledge of sound is certain to be useful. Thermodynamics may be of greater interest to the engine designer than to the plane designer, but the plane designer has to think of cooling. Aerodynamics is only a special branch of hydrodynamics. The writer in working with graduate students has found that graduates in mathematical physics when they had once mastered the language of mechanical drawing, had some advantage over graduates in mechanical engineering.

Again, since the airplane is such a refined structure, applied mechanics is highly important. The aeronautical engineer should know as much of applied mechanics as the civil engineer.

Materials of construction and metallurgy are of obvious interest in the design of aircraft where weight limitations are added to the other problems of utilization of materials.

Airplane design is also a matter of visualization, and there of course descriptive geometry is the best introduction.

Aeronautical engineers should be first of all mechanical engineers, and the fundamentals of mechanical engineering are well understood and need not be enlarged upon here.

The Ideal university curriculum would probably be two years of mathematics and physics, two years of general engineering, and two years of aeronautical specialization. Such a curriculum has the disadvantage of being too lengthy, which makes it impractical for students.

A more practical alternative is four years of undergraduate work in mechanical or civil engineering, with special emphasis on the basic subjects of mathematics, physics and applied mechanics, followed by one year of graduate work in aeronautics.

Where only four years are available, specialized study in aeronautics should be restricted to the senior year.

It may be considered that one year is a short space of time in which to master aeronautical engineering. But a profession is never mastered at school. The university should be content to give a sound basic education, and a sound introduction to the profession itself.

Introduction of Aeronautical Problems in other Courses

It will be extremely helpful to the aeronautical student, and certainly not harmful to other engineering students, if aeronautical problems are introduced in non-aeronautical courses.

For example, the classical problem of the flagpole in trigonometry can be varied by calculation of gliding angles, etc.

In College physics, problems in fluid flow taken from aerodynamics will be interesting.

In a course in dynamics, illustrations of airplane oscillation can be introduced.

Teachers of applied mechanics will find many beautiful problems in the calculation of wing spars under combined

compression and bending, or struts under direct compressive load coupled with side loads due to air resistance.

Such examples could be multiplied indefinitely.

Introduction of Aeronautics in Shop Practice

Whether shop practice properly belongs in a college curriculum or not is a difficult question. If university students do receive practical instruction in shop methods, instructors will find that certain parts of the airplane can be readily built —ribs, struts, or wing spars for example, and that airplane parts are easier and cheaper to build than the parts of other engineering structures. It is possible in a college workshop to build a glider that will fly, or even a light airplane that will fly. It is just possible that construction of this character will make shop classes more interesting than the conventional work of to-day. The construction of an airplane model is a splendid exercise in practical mechanics. In over ten years experience in teaching aeronautical students, the writer has found but one man who was capable of constructing an accurate wind tunnel model. This does not give a high idea of the mechanical skill acquired in our engineering schools.

Aeronautical Options

It is the writer's most decided opinion that owing to the present public interest in aeronautics, the number of complete aeronautical engineering courses now being established, is perhaps too large, and that disappointment may ensue both for the universities and technical schools establishing such courses, and for the graduates of such courses. On the other hand, the writer believes that almost every technical or engineering course can usefully include an aeronautical option, and that for very definite reasons.

Engineers of almost every branch are likely at some time or other to come in contact with aviation.

Civil engineers may be asked to lay out airports or to design hangars, or mooring masts for airships.

Electrical engineers may be engaged in the lighting of airways.

Metallurgical engineers may be asked to pass upon problems in the metal construction of aircraft.

Chemical engineers may be consulted on the difficult problems of doping fabric, or of resisting corrosion in metal pontoons.

As aviation is likely to become an industry of giant proportions, engineering students will find it to their great advantage to have followed at least a term's work in the elements of aeronautics.

A student in civil or mechanical engineering may also decide to proceed to graduate work in aeronautics, and an elementary study of aeronautics will be invaluable to him in such graduate work.

It seems perfectly logical and practical to allow a student the option of taking Fundamentals of Aeronautics instead of such a subject as Hydraulic machinery or Power Plant Design.

The syllabus of an elective or optional course in aeronautics should include the elements of aerodynamics, with suitable problems; the basic principles of the airplane, with suitable problems; a consideration of the modern airplane; and a brief study of airplane operation, with some attention paid to airways, airports, and aids to navigation.

Classification of Aeronautical Engineering Careers

It is interesting to classify the various phases of aeronautical engineering already emerging. We may list:

1. Aerodynamics and research.
2. Airplane design and construction.
3. Airship design and construction.
4. Aircraft engine design and construction.
5. Air Transportation.

Aerodynamics and research should appeal particularly to the man with an analytical mind, interested in mathematics and physics. The scope for such men is at present limited. Teaching and work in the various research laboratories of the universities and of the government alone are open to them. While the airplane industry is fully alive to the value of re-

search, it is not as yet engaging largely in research, but rather in experimental construction.

The men wishing to enter on airplane or airship design should have a combination of analytical and practical faculties. However a man who is more analytical than practical may be more successful in aircraft design than in many other branches of engineering. There is at present a demand for young aeronautical graduates in design work, the chief engineers of the largest companies are without exception young men and there is apparently more promise of rapid advancement in aircraft design than in other engineering work. There is a danger however that this bright prospect will attract too many men. Consolidation of airplane manufacturers, now already in process will also reduce the number of graduates that the industry can absorb.

In aircraft engine work, analysis plays a far lesser share than in airplane design and this branch of the profession should attract only men of real native ingenuity and mechanical bent. In the writer's classes, ten men select airplane design to one man selecting engine design. Yet the opportunities in the engine field are numerous.

While the airplane operating companies are at present chary of taking on engineering graduates, there is not the slightest doubt that eventually technical men will lead in many phases of air transport work. A career in air transport should appeal to the young engineer who is not so fond of purely technical work, and likes outdoor activities, executive responsibility, and contact with men. The extension of air transport in the United States seems now assured and should be on a tremendous scale.

Equipment Required

The equipment required for complete instruction, particularly where graduate study and research is contemplated, is extensive and quite expensive.

A modern wind tunnel suitably housed is likely to cost at least $50,000 with its auxiliary equipment. The other main items would be: a power plant laboratory capable of testing

air-cooled engines; a model shop; an aeronautical museum; a structural laboratory; a full flight laboratory; and perhaps an airship laboratory.

When merely an aeronautical option is offered, a small 9 inch wind tunnel can be readily constructed for class room demonstration.

Qualifications of Staff

During the last two years, the writer has received many inquiries from universities and technical schools, regarding instructors in aeronautical subjects.

A competent teacher of mechanical engineering who has read some of the excellent textbooks now available may perhaps undertake the aeronautical option previously outlined, even though his presentation may perhaps lack authority.

If anything like a complete aeronautical course is contemplated, specialists are essential. A man, however, well qualified in mechanical engineering for example, will not find it possible to teach aeronautics. A complete faculty should consist of a well qualified aerodynamicist; an experienced airplane designer; an experienced engine designer; and at least one man who has had practical experience in air transport operation.

Aeronautical Engineering Instruction Likely to be Concentrated at Certain Centers

The intense popular interest in aviation has had its reflection in university circles. There are already given more or less complete course of instruction at the following universities and technical schools: California Institute of Technology, Massachusetts Institute of Technology, New York University, Purdue University, University of California, University of Detroit, University of Minnesota, University of Nebraska, University of Wisconsin, University of Washington, and the University of Wyoming. This list is probably incomplete. Many of these schools have received substantial support from the Daniel Guggenheim Fund for the Promotion of Aeronautics.

The question arises whether every school of engineering should have a department of aeronautics. This does not seem advisable to the writer. Aeronautical engineering is not an introduction to practically every industry in the manner of mechanical engineering. It is a highly specialized profession. The number of aeronautical graduates that can be absorbed is not indefinite while there is at the present moment a real demand for young graduates, it is not likely that this will continue, and it is believed that the present output of existing institutions is likely to meet future requirements.

In deciding whether or not a complete course of aeronautical instruction should be included, the dean of a school of engineering would do well to consider whether there is any neighboring industrial center in aviation, and whether there is a real demand for such a course of instruction, or a temporary pressure due to the general glamor of aviation.

Instruction in Flying

It is the writer's opinion that no matter how necessary it is for the aeronautical engineer to learn to fly, instruction in flying is not properly a function of the university. The type of men who are competent to teach technical aeronautics are not always well qualified to direct the activities of a flying school, and the responsibility of flight training is very high. It is far better to utilize the facilities of the many private flying schools now available, or to seek alliance with the Army or the Navy Air Service Reserves.

An Opportunity for Trade Schools

Airplane and engine constructors claim that they find it harder to fill positions for draftsmen than positions calling for college graduates. Detail design in aviation cannot readily be picked up. It would seem that trade schools should have a real opportunity in training men in airplane drafting and shop methods. This opportunity does not seem to have been grasped as yet.

Specialized Courses of Instruction

The following is a fairly complete list of the specialized courses of aeronautical instruction now offered in our universities and technical schools.

1. Aerodynamics, Theoretical.
2. Aerodynamics, Experimental.
3. Advanced Aerodynamic Theory.
4. Advanced Dynamics of Aircraft.
5. Technique of Aerodynamical Research.
6. Full flight Research.
7. Theory and Practice of Airplane Design.
8. Advanced Theory and Practice of Airplane Design.
9. Advanced Structural Analysis of Airplanes.
10. Materials and Methods of Airplane Construction.
11. Rigging and Assembly of Airplanes.
12. Structural Laboratory.
13. Propellor Theory and Design.
14. Airplane Engines.
15. The Airplane Power Plant.
16. Thermodynamics of the High Speed Internal.
17. Aircraft Engine Design.
18. Aircraft Engine Laboratory.
19. Aerostatics.
20. Airship Theory.
21. Airship Design and Construction.
22. Hydromechanics of Aircraft.
23. Seaplane Theory and Design.
24. Aerial Navigation.
25. Aircraft Instruments.
26. Aeronautical Meteorology.
27. Economics of Aircraft Transportation.
28. Air Transportation.
29. Airports and Airways.
30. Statistics and Accounting in Aviation.

Purely as an illustration the syllabus of one year graduate instruction at New York University follows:

COURSE OF STUDY—AERONAUTICAL ENGINEERING AND AIR TRANSPORT

Graduate Year—First Term

Course No.	Name of Course
Engr. 70	Thesis and Independent Reading
A.E. 70	Theory and practice of Airplane Design, 5
A.E. 71	Aerodynamics, Theoretical and Experimental, 3
A.E. 72	Airplane Engines and Installation, 2
M.S. 75	Advanced Applied Mechanics, 3
A.E. 110	Advanced Aerodynamic Theory, 2
A.E. 111	Materials and Methods of Airplane Construction, 1
A.E. 74	Air Transportation, 2 or
M.E. 73	Internal-Combustion Engines, 3

Total—18 or 19 credit hours.

Graduate Year—Second Term

Engr. 80	Thesis and Independent Reading
A.E. 84	Air Transportation, 2
A.E. 81	Propellor Design, 2
A.E. 82	Advanced Theory of Airplane Design, 4
A.E. 83	Airships, Theory and Design, 2
A.E. 125	Applied Thermodynamics of the High-Speed Internal-Combustion Engine, 1 or
A.E. 87	Aviation Accountancy and Statistics, 1
A.E. 85	Economics of Aircraft Transportation, 1
A.E. 120	Seaplane Theory and Design, 2 or
A.E. 121	Materials and Methods of Airplane Construction, 1
A.E. 122	Elements of Navigation, Aircraft Instruments, and Meteorology, 1
A.E. 123	Advanced Dynamics of Aircraft, 2 or
A.E. 124	Advanced Structural Analysis, 2
A.E. 126	Aero-Engine Design, 2

Total—18 or 19 credit hours.

It will be noted that the work at New York University has been subdivided into only two options—Aeronautical Engineering and Air Transport, and that the graduate course is only of one year's duration.

Probably certain subjects should be required of all aeronautical students, such as

1. Aerodynamics Theoretical;
2. Aerodynamics Experimental, and
3. Theory and Practice of Airplane Design.

Specialization at New York University has only been carried to a slight degree. As time goes on, there will be a greater degree of specialization in the five main phases listed above. The grouping of subjects for further specialization is obvious.

Where a two year graduate course is possible, formal instruction should cease with the first year and the second year should be devoted to thesis and research work.

It is impossible in this short paper to discuss the methods of instruction to be adopted for each of the above subjects. The following reflections may be of interest.

In teaching aerodynamics, theoretical conceptions and fundamental principles are of more importance than data obtained from the laboratory.

All students should at some time or other work in the wind tunnel.

In design work it is possible and desirable to carry through the complete design of an aircraft during the academic year.

Aeronautical Education a Fascinating Field

We have voiced a word of warning as to the possibility of too much aeronautical instruction being offered. The fact remains that aeronautical education is a fascinating and pioneer field, with ever changing conditions. It offers unlimited scope and interest to the personnel and the institutions fortunate enough to be engaged in such work.

"AMERICAN ENGINEERING COUNCIL"*

ADDRESS BY L. W. WALLACE

Secretary of the Council

Many of you have heard me speak before, hence it is not necessary to go into any detail as to the organization and method of operation of American Engineering Council. The purpose of the Council is well expressed in a sentence from the last page of the document presented to you so ably and forcibly by Mr. Wickenden. It is this: "A greater appreciation by the public of the work of the technical professions in present-day civilization." It was for that purpose the Council was organized and why it has been functioning for more than eight years.

I am reminded that I am not among strangers, because I have been a member of this organization for many years. A hasty glance over your registration list discloses that something over thirty of those registered have, in some capacity, participated in the work of Council. In the present membership of the Assembly of Council, which is its policy-forming body, are the following members of your organization: Professor Boss of the University of Minnesota, Professor Dodds of Ames, Professor Eastwood of the University of Washington, Dean Greene of Princeton, Dean Kimball of Cornell, Dean Marston of Ames, Professor Rittman of Carnegie Institute of Technology, Professor Robinson of the University of Vermont, Professor Scott of Yale, Professor Withrow of Ohio State University. These men compose one sixth of the membership of Council.

Through the years we have had as president of the Council, Dean Cooley of Michigan, and Dean Kimball of Cornell University. Hence, the great technical institutions of the country have had some part and parcel in the work of Council.

* Presented at the 37th Annual Meeting of the Society, Ohio State University, June 19–22, 1929.

Our activities deal largely with the Federal Government in relation to national problems of an engineering character. We thought when we began to function that probably it would be difficult to find enough to do. That is not the case. Of the several thousand bills that are introduced in each session of Congress there are a very large number that have a material engineering content. All such bills are given careful study. We take some definite position with respect to many of them.

There are now four great engineering questions confronting the Federal Government. One of them is flood control. In our judgment, no adequate solution of the flood problem of the United States has been evolved.

The Council, through a very able committee, one member of which, President Morgan, is to speak to you this afternoon, has studied that question. From the flood of 1927 to date we have pronounced emphatically that there has not been a sufficient engineering survey made of the Mississippi flood problem to justify the Federal Government proceeding with any plan.

We have recently emphatically stated that the so-called Jadwin Plan is unsound, both from an engineering and an economic standpoint, and that the Federal Government should not irretrievably commit itself to that plan.

In the last session of the Seventieth Congress Senator Watson, of Indiana, and Senator Couzens, of Michigan, respectively, introduced a bill providing for the setting up of a Federal Commission with reference to communications. In substance these bills provide for a Federal Communications Commission which shall have supervision over all agencies of communications, such as radio, telegraph and telephone, somewhat similar to the Interstate Commerce Commission.

There is a serious question as to whether we need more Federal regulation. There is a question as to whether the Federal Government should further control business activities. Recognizing the importance of the questions involved, the Council has formed a committee to study the fundamental and underlying principles involved in the proposed legislation, and to advise Council as to the position it should take. Upon the

basis of such a report our Administrative Board will make a decision as to whether we shall approve or disapprove of such legislation.

Growing out of some of the dam failures in the western country a few years ago, there has arisen agitation for legislation, state and national, with reference to the design, construction and operation of dams. The Council has appointed a committee to make a thorough study of that subject and to determine whether or not state and Federal legislation is needed with reference to the design and construction of dams. At the present time we do not know whether such legislation is or is not needed. However, we are becoming informed so that we may act intelligently when such legislation is proposed.

Water resources and their control is of great moment at the present time. Proposed legislation relating thereto is now pending in Congress and in several state Legislatures. A three-fold problem exists, to wit: the relation between the Federal Government and the several states with reference to interstate streams; the relation between two or more states with regard to a river flowing through or between each; and third, a purely state problem with respect to intrastate streams.

There are now pending in Congress four or five bills bearing upon the question of water resources and control. In several State Legislatures legislation of a similar character is pending. An endeavor is being made to find an answer to this important question: What shall be the fundamental policy of the Government and the several states with reference to water resources and their control during the next two or three decades?

In preparation for an answer to that question we have also appointed a competent committee to make a thorough study of the problem.

Another important engineering matter is the reorganization of the Federal Government as it relates to the scientific and engineering activities of the Federal Government.

As most of you know, for something like thirty years the civilian engineers of the United States have contended for the

establishment of some agency of the Federal Government wherein would be concentrated all the engineering and allied technical activities of the government. In the last session of Congress, Congressman Wyant of Pennsylvania introduced a bill which proposed to establish, in the Department of the Interior, a major subdivision wherein would be concentrated all the engineering, construction and architectural activities of the Government.

Extensive hearings were held on that bill. The proponents of it put up a strong argument. The bill was not opposed in any particular sense except by the Engineering Corps and the Bureau of Public Roads. I feel that if it were not for the opposition of the Engineering Corps of the United States Army, within a short time we would have a real Department of Public Works. Such a department is greatly needed. It would insure better design and execution of plans and it would mean an enormous saving to the American people.

The four or five engineering problems mentioned are the major tasks immediately ahead of Council. There are, however, many other pending bills to which we are giving continuing attention.

However, all of our activities do not pertain to legislation alone. We cooperate actively with many national agencies in many directions. We have representatives on various Federal committees. We also carry on research from time to time. You have heard of the reports, Waste in Industry, and Safety and Production. Recently we issued a report on Traffic Signs, Signals and Markings, which was part of the work of the Hoover Conference on Street and Highway Safety. This report is designed to bring about uniformity of practice throughout the nation with respect to traffic signs, signals and markings. Such a uniformity of practice will expedite traffic and reduce accidents.

The report has met with very widespread comment. A committee is being organized in each state to bring the report to the attention of all municipal officials. I see Mr. Cushman in the audience. He has been very active in this connection in

his section of Tennessee. There are also others here who have been active in their respective territories.

We participated in the preparation of the report on Recent Economic Changes under a committee set up by Mr. Hoover when he was Secretary of Commerce. We prepared two of the major topics of the report. One was done under the supervision of Dean Kimball and the other under Mr. Alford.

During eight years we have spent something like $200,000 for research of the character mentioned. In addition to the foregoing lines of work we are constantly rendering services to individuals. We receive inquiries relating to a variety of subjects, from knowing what the British Ambassador is going to do and when the Belgian Ambassador is to sail for Europe, to very commonplace matters.

From time to time engineers come to Washington who are not familiar with the resources of the great departments. They are not sure to what man or department they should go for some particular line of information. We are in a position to direct them effectively and promptly.

As an illustration of this line of service I shall cite a case. A few weeks ago the Minister from Uruguay asked the State Department to recommend some American engineers who would be competent to go to Uruguay to help develop hydro-electric power along the Negro River. The State Department turned to the Department of Commerce, which in turn came to us. We prepared a list which went back through the Departments to the Minister of Uruguay and from there to the Director of Public Works in Uruguay. It was a circuitous route, nevertheless the names of prominent engineers got to Uruguay through the American Engineering Council. Several prominent engineers have received foreign commissions during the last eight years because of such a route and contact.

We have established a Committee on Engineering and Allied Technical Professions. This committee is to make a thorough study of the professional and economic status of the engineering profession. It is to be a cooperative effort on the part of the Council and its member-organizations. The American Society of Mechanical Engineers has a like committee func-

tioning. The Electrical Engineers have also formed a committee. We expect to make a thorough canvass of the situation to see what the present professional status and influence of the profession is, and upon the basis of such an analysis determine the course of the future.

We hope, through such an effort, to be in a position where, when a serious situation arises, as it did between the city governments of New York and Chicago and their engineers, the Council will be able to send a man into those situations fully equipped so that he may advise the local engineers as to the wisest course to pursue under the circumstances.

This has been a hasty presentation, but I have endeavored to impress upon you that Council has been going forward; that it is now in a strong position; that it represents 57,600 of the leading professional engineers of the United States; that it does have influence and standing among the governmental officials of Washington, that Congress is paying heed to what Council is saying; that Congressmen desire to know its position with respect to some of these great questions; that its advice and guidance are sought. With these things being true there is no reason why the engineering profession should not lead in many directions and materially aid the American people in solving some of the profound problems confronting them.

This is the day of the engineer. Do not be pessimistic. Eliminate the inferiority complex and cease comparing yourselves unfavorably with the lawyers and the doctors. We need make no apologies nor bend any knees to those two professions. We are in the front rank of influence and leadership, and the degree to which we shall yet go will depend upon how much you men, your alumni and your students, support the altruistic movement represented by the American Engineering Council.

SOME REFLECTIONS ON ENGINEERING EDUCATION *

BY E. A. HITCHCOCK

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What I have written are viewpoints and expressions worth no more than the opinions of one man and therefore debatable, although they are based upon observations made during a period of thirty-three years of engineering educational experience both as a student and as a teacher and also of ten years of intimate industrial experience with three enterprises.

Forty-three years ago, eighty-two fairly ambitious young men knocked at the door and were admitted to what was known then as Sibley College. The speaker was $\frac{1}{82}$ part of that group. We had very little conception of what this mysterious study of engineering really was and to what it would lead, but, nevertheless, it was our selection because the work prescribed called for contact with those fields of activity in which we were quite confident we had an innate and absorbing interest. We accepted, without question, everything which was prescribed, never once asking why the curricular content was thus and so or why it took exactly four years to train an engineer rather than three and a half, or four and a half, or even five. We had absolute confidence in the judgment and wisdom of those who were responsible and accepted everything that was passed to us just as we drank grandmother's sassafras tea which for generations had been pronounced good for the blood. I cannot recall that even once during that four-year period did I hear any of my classmates raise an objection to the character of any courses or to the methods of any teacher. The nearest approach to any such attitude of mind was in a course in the sophomore year for

* Presented at the 37th Annual Meeting of the Society, Ohio State University, June 19–22, 1929.

which Anthony and Brackett's textbook in Physics was used. The very strongest expression which I can recollect was, "Well, what did you get out of that stuff today?" And even to this day I have never been able to figure out why a text of that character was used on innocent sophomores unless it was because the professor in charge that year or the year before, was the author of the book. One fact about this subject not forgotten in all these years is the title of the book.

During the usual four years that group of eighty-two boiled down to fifty-four, or 66 per cent. This shrinkage was due very little indeed to failures; in fact failures were most unusual, and for a student to be reported as having failed out of college was looked upon with awe and mentioned only in a whisper. Our feelings at such times were of a graveyard quality. You will hardly believe it, but the grades we obtained during those four years were simply incidental and of little interest. The kidnapping of the subjects was our objective.

Armed with our diplomas, figuratively speaking, for we had sense enough to keep them in the dark, we landed in sundry places; and then came a grand awakening. I was fortunate in working in the same rooms in which that wonderful pioneer in steam engineering, George H. Corliss, spent the latter years of his life. Here I " played " for over two years, ten hours per day, thirteen hours much of the time, and while it was a wonderful inspiration to be in such an engineering atmosphere it was indeed a great surprise to discover that very little of the matter which we had labored for during four years was used in a way that one was very conscious of it. Drawing, trigonometry, shop experience, the simplest principles of Physics, and mechanics highly flavored with common sense were about all that entered into the design work of this nationally known industry, The Corliss Steam Engine Company of Providence, Rhode Island. To illustrate this point it was related to me that at one time one of the draftsmen was designing a 60-inch steam cylinder and, upon going to Mr. Corliss with a theoretical formula for thickness of cylinder walls, asked if it would be correct to use this formula. Mr. Corliss' reply was, "Yes,

figure the thickness by that formula and then add one inch." This adding of inches here and there, or making certain allowances based upon experience and judgment were factors with which the student was not very familiar in those days. In fact many students were inclined to question very seriously their value to the engineering world and what they really could do. A few years ago an alumnus of this University in discussing with me this question of engineering education stated that just after his graduation he questioned himself as to just what he knew, came to the conclusion that this was very little, and then proceeded to study again many of the subjects for which he had received credit in college and incidentally good grades. Another similar case is one whose name is very well known in the engineering world, a graduate of this institution. His statement to me was that when he thought of the four years he had passed through and the little he knew and could do, he felt like going out and committing suicide. This man obtained most excellent grades.

I am fearful that to-day many of our graduates are raising similar questions, although to a much less degree for the simple reason that the demand of industry is such that a man with one-half of a collegiate engineering education can find a place where the opportunity is dependent more upon the character of the man and not so much upon the grade of his engineering education.

Many students past, and yes, present, have good grounds for discrediting the value of some of the material which is passed out to them. In other words in many directions our power factor is considerably below 100 per cent. There is much educational wattless in the curriculum content which does not assist the student in analytical constructive thinking. In other words, there is considerable froth above the solid matter which as you know adds very little to the fundamental content. Froth is mostly gas and tickles our sensibilities; the same is true of some of the material which is passed out to the student. He is pleased at the time, but later, after graduation, discovers that this college food was of little real value and that he has been fed on rather antiquated material. Dur-

ing the past seventeen years, eight of which were spent in industries where several of my former students were employed, I have had considerable opportunity to learn of their views and the views of other students relative to our curricula, methods and attitude.

An instructor does not realize it, but he is constantly under the closest scrutiny. The student will instantly spot sham or pretense and will condemn partiality. I have had it reported to me by a disinterested senior that it was very apparent to him that the instructor was partial to one group from one department in comparison with another group in the same class from another department. The teacher may be unconscious of such a position and therefore may be excused, but if partiality is detected the reputation of that instructor certainly suffers. I have known an upper classman to test out individual partiality in this way: An exercise in machine drawing calls for a design which can be worked at home. The student makes two drawings which are identical, one for himself and one for a friend in his class. Then he compares the resulting grades. Several years ago an alumnus of our College related to me, with apparently considerable pleasure, how to one professor was submitted a drawing which had been made the year before and graded by this same instructor, more to see how he would grade this same drawing a year later than to put over something which was not proper. The student's pleasure was very keen at finding considerable difference in the grades.

The college student wishes to be looked upon as a man and he resents any implication that he is not square or is dishonest. I do believe that 99 per cent of our boys have qualities which warrant implicit confidence on our part. If we show our confidence by word and action it will be respected. One of our former students, who twelve years ago was in my employ, stated to me at that time that during his college associations and contacts with his engineering professors he did not know of a single student in his class who would put over anything irregular in examinations if the instructors had

implicit confidence in the students and expected them to play the game on the square.

In looking back over the first nineteen years of my teaching experience at this University, 1893 to 1912, I can see several directions in which my methods deserved severe criticism, and I hope the good Lord has forgiven me for I certainly have had a change of heart. Freshmen and sophomores were not known to exist on the campus, for contact was with juniors and seniors only, requiring, I assumed, a superior quality of intelligence and teaching methods, giving terrific examinations, then sometimes no examinations if some investigation work conflicted; at such times the students were considered a nuisance. Other misdeeds of which I have been guilty include shooting over the heads of the students; lecturing or putting a demonstration on the board, judging my effectiveness by the reaction of the best men in the class; giving little consideration to the average man who needs the most help and guidance; in correcting examination papers, passing very lightly over those of the high grade but scrutinizing most carefully that of the average man; a disregard of the timidity and sensitiveness of some students so that as a result of answering their questions in a certain way they forever fortified themselves against me. I hoped this attitude was of the moldy past; but in this I was mistaken. A short time ago I learned of one of our upperclassmen who vowed he would never again ask a particular teacher another question on account of the character of the reply he was given when he politely asked a question. There certainly is no place for ridicule and sarcasm in the classroom. I have no sympathy for this hard-boiled attitude some teachers take upon themselves. They certainly have mistaken notions as to the essential qualifications of a good teacher. We do not use such tactics in the raising of our children and these students are just that only of a larger growth. One of the greatest teachers our College has had, a man after whom one of our buildings is named, looked upon a failure given in a subject as a reflection upon his teaching. Sometimes when someone in the class did not seem to be interested this instructor was very

much concerned and questioned his ability as a teacher. I have known him to throw away a set of midterm papers and give another examination because the standing of the class as a whole was too low. At the present time the attitude of some instructors is one of great concern if a certain percentage of students do not fail. It makes no difference how exceptional a class may be, how heavily the students may be loaded, or how one instructor makes demands upon the students' time without regard for other teachers; that traditional percentage of failures must remain the same. An instructor who fails few, gives to three-quarters of his class A's and B's, is referred to as giving snap courses. It never occurs to critics, or they will not admit it, that very likely the high grades are due to the intense interest of the student in the subject, the direct result of the ability of the instructor. That interest may be due largely to the excellent personality of the teacher and his personal interest in the progress of his students.

We are dealing with very valuable material which industry is demanding we put in condition for use and it is our duty to make it the very best possible and not to throw so much on the junk pile. As stated above, in my day sixty-six per cent of our group made the "riffle." You know what it is today, very, very much less: about thirty-five per cent. One reason for this is that many ambitious teachers just keep adding on a "little bit more." That action, coupled with poor preparation about which many of us have been crying, certainly presents a very high hurdle for the student. I have compared the required work in the curricula of civil and mechanical engineering of forty years ago at this University with that required at the present time. We are constantly referring, with considerable satisfaction and self-glorification, to many of the men who covered these curricula of forty years ago. But, for some unknown reason, in order to turn out men who will equal these of old we must tack on an hourly requirement of practically 15 per cent more, or, in other words, we are today requiring the equivalent of two additional quarters of work in comparison with that of forty years ago or in comparison with the present requirements of our colleges of Agriculture, Arts, Commerce, and Education on this campus.

Now on top of this additional load, made increasingly so by poor preparation—which may be questioned—a cry went up to Heaven that something must be done to improve scholarship. A discovery was made which was looked upon as a panacea for our educational aches and pains. The old system of decimal grading had been worn threadbare. Although it told the truth in the judgment of the instructor, it was of no particular interest to the student, so it was thought. He evidently wanted something more attractive held up before him as an incentive to greater effort. Therefore, following Boy Scout methods, systems of grading with points attached have been adopted by many institutions. Those engineering colleges holding to the decimal systems are certainly to be congratulated, for of all the unscientific methods of grading which are a reflection upon the underlying principles of engineering, the point system as now used stands at the front. You may ask, "Why do you have it then?" Our answer is that this College is only about one-sixth of the University and college autonomy does not exist. The majority rules. The most detrimental result as I see it is upon the student after graduation. He has spent four or more years in an atmosphere where the principal objective is getting an A or a B or a C rather than a knowledge of his subject. His position after graduation will be foreign to that of service for it will be flavored highly with a desire to be graded for everything he does. For a long time his attitude will be: "Well, what do I get for it?"

At the time of the adoption of the point system at this University certain regulations were introduced relating to probation and dismissal. It was soon discovered that this change resulted in greater leniency than before and consequently the screws were tightened further. About this time a wave of educational pessimism hit us. Most students were going to the "bow-wows" and consequently were here for a good time only. That feeling was certainly a false alarm so far as our College was concerned, at least that condition of affairs I have never yet discovered. Nevertheless the screws were given a few more turns, more hurdles were erected, so that to-day we

have only *seven* rules by which our students may be dismissed from college. I would be interested to know the institution which can equal us. Nothing like being distinctive in some respect.

It is so easy for a faculty to adopt regulations which make it increasingly difficult for students to continue and consequently which must cast discouragement in their pathways. The students have nothing to say about it although spending their good time and money at a plant which has been erected to serve them.

One of the greatest criticism of an institution of this kind, where it is a case of mass production, is that we are attempting to put all students through the same knothole regardless of their different characteristics and ability, not realizing fully that in the engineering world with its very high diversification there is a place for nearly every grade of engineering student. What we need is more individual contact between instructor and student, and a greater personal interest in the student's activities and ambitions. Not once during my four years was I conscious of any instructor's taking any interest in my progress, and not once did faculty and students get together for a good time as is being done today at many institutions. The many human problems, which in a few years will concern our students of to-day, demand that we hang a little brighter humanity lantern over our own doorsteps.

The engineering field to-day is crying for men, more and more men. The responsibility of the engineer is growing rapidly. Mr. Lewisohn and other industrial leaders are urging that we turn the thoughts of our students into channels not navigated by engineers heretofore. This situation demands that we look very carefully into the possibilities of every man who enters our College, without regard to where he may stand on a so-called intelligence test or whether he pulls down A's and B's. Our position with the individual student should be based not only upon his ability, but also to a much larger degree upon his honesty, his dependability, his industry, his initiative and his considerateness: qualities which cannot be determined by written quizzes and final examinations.

No student should be the recipient of honors whose scholastic standing can be attributed to his native ability only, no particular effort having been put forth on his part; and on the other hand no student should be denied graduation who is intensely interested in his work, who has put forth his best efforts, and who has met the requirements to a reasonable degree. I am fearful that some of us during recent years have quite forgotten how, during the past thirty or more years, our institutions have managed to turn out such high grade men without the childish systems of grading which are now being used at many engineering colleges.

We are desirous, of course, of sending out the best possible men, those who in many lines are geniuses to a greater or lesser degree. In George S. Bryan's book entitled "Edison, the Man and His Work," he quotes Edison as saying that genius is 1 per cent inspiration and 99 per cent perspiration. If that is so—and we will accept the figures within reasonable limits until someone disproves it—are we not missing the mark in many directions through the character of the work given, the manner in which it is given, and the methods used in rating our students? Are we making our subjects so interesting that our boys will have a mania for hard work which is productive of "perspiration"? "Inspiration" is bound to be there somewhere. Inspiration in a lazy man is not worth a nickel.

Dr. Charles F. Kettering, of the General Motors Company, an alumnus of this University, was our Commencement speaker last week, and he gave us many excellent points to think about. One of these has a direct bearing upon the type of men we should train for industry. He was speaking of the job going after the man. I quote:

"I want that job to get hold of this fellow so hard that no matter where he is the job has got him. The first thing he thinks when he opens his eyes in the morning is his job. There it is sitting on the foot of the bed ready to grab him and it is sitting there when his eyes close and he passes out of consciousness. That is the only kind of a fellow you can trust to do a real good piece of work, one whose job has hold of him so hard he can not get away from it."

SELECTED PAPERS OF THE 1929 SESSION OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS

HEAT POWER DIVISION

The following papers were presented before the Mechanical Engineering Session of the Summer School for Engineeering Teachers, held at Purdue University in 1929. They will shortly be reprinted in bulletin form as one of the series of Summer School publications. They will be followed in succeeding numbers of the Journal by selections from the papers presented before the Machine Design Division and the Production Division of the Summer School.

The papers here published are those which relate most directly to methods of teaching. Through the cooperation of the American Society of Mechanical Engineers, papers of more definitely technical content are being published in *Mechanical Engineering* and in the *Transactions* of that Society. The reader is referred to those publications for further papers of the Heat Power Division. The papers published by the American Society of Mechanical Engineers will be bound together in a single cover as reprints for distribution in the near future.

PURPOSES AND SCOPE OF COURSES IN HEAT ENGINEERING*

By A. A. POTTER

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I. Purposes

The main objectives of instruction in heat engineering are:

1. To teach the student the fundamentals of thermodynamics so that he will be able to solve problems involving thermal processes such as heating, cooling, expansion and compression of fluids.

2. To familiarize the student with the principles which are basic to efficient power production by external and internal combustion plants; also refrigeration and compressed air.

3. To teach the student the application of the principles of chemistry and physics to the solution of problems pertaining to fuels, combustion and heat transfer.

4. To acquaint the student with the functional purposes and parts of steam and internal combustion power plant equipment, refrigerating machinery and air compressing systems.

II. Scope and Methods of Instruction

Every engineering graduate should have a general knowledge of the following:

1. **The Effect of Power, Artificial Heating and Mechanical Refrigeration Upon Human Progress.**

(*a*) The most significant movement of our times is the transfer of labor from men to machines and the resulting high cost of man-power. Our age is being referred to as the "Age of Mechanical Power." Engineering has made possible the substitution of mechanical power for human and animal labor to such an extent that modern industrial activities and even

* Presented at the Summer School for Engineering Teachers, Purdue University, June 27, 1929.

the family life of a civilized people are becoming absolutely dependent upon mechanical power.

It is estimated that in the United States about eight mechanical horse-power are available per capita of population. This enormous amount of power at our command has resulted in high standards of living so that a large portion of our population enjoys automobiles, electric lights and many other conveniences unknown fifty years ago. In industry there is a definite relation between the productivity of workers in different lands and the mechanical power they have at their command.

It is generally known that power at low cost is primarily responsible for the progress of our age. The student must realize that through mechanical power, labor may be saved and human drudgery lessened. It is essential, however, that the student be guarded against a wrong philosophy of life. He must *not* develop the habit of measuring individual accomplishment in terms of his control over his fellowmen. He must not regard mainly aggressiveness, domination and self-assertion, but should recognize true ability, character, loyalty and modesty among his friends and associates. He should use his talents in order that man may have more and cheaper power, but must guard against depreciating human values.

(*b*) Human comfort is greatly affected by the means used for heating, cooling and ventilating of buildings. Artificial heating has extended the area of industrial activities by removing climatic limitations and it has made possible warm and well ventilated homes during the coldest weather. Modern methods and relative costs of producing comfortable homes, offices and factories should be known to the student.

(*c*) Mechanical refrigeration is of great importance, as it enables certain industries to produce better goods and to market their products in better condition; facilitates distribution of foods and lengthens the period of consumption, thus reducing demand fluctuations; and enables man to benefit at all seasons of the year by foods from distant parts. The different systems for producing refrigeration and their relative economies should be known to the engineering student.

2. **Stimulating the Student's Interest in Heat Engineering.** To interest the student in heat engineering he should be familiarized very early in his course with the effect of power, artificial heating and mechanical refrigeration upon human progress. This can be done through a series of lectures, preferably illustrated, which should be delivered during the Sophomore or even during the Freshman year. Considerable ground can be covered in from eight to fifteen lectures. They should be required of all engineering students.

Are engineering teachers making sufficient effort to interest their students in the more general problems as they affect human welfare? References to the lives of engineers and to engineering works should supplement such lectures. Then the student should be expected to demonstrate his knowledge through a written examination. The teachers of heat engineering to juniors and seniors should also take every possible opportunity to relate their instruction to actual cases. Use should be made of the papers presented before engineering societies, articles in the technical press and biographies of master engineers. To what extent are mechanical engineering teachers making use of the biographies of John Sweet, Walter Kerr and those of other master engineers which were prepared under the auspices of the American Society of Mechanical Engineers?

3. **Fundamentals of Thermodynamics.** Every engineering student should have an introductory course in this subject, which should include the following topics:

(*a*) Heat and work units: Temperature and entropy as measures of heat energy (mechanical and electrical energy analogies). Thermal capacities. The first and second laws of thermodynamics.

(*b*) Properties of gases: Fundamental laws of gases. (Boyle's, Charles', Joule's, Dalton's, Avogadro's). Thermodynamic processes of gases including constant pressure, constant volume, isothermal and adiabatic heat changes. Entropy changes during processes with gas. General equations for the flow of gases.

(*c*) Cycles of heat engines using gas including the Carnot,

hot air and internal combustion engine cycles. Economies and limitations of the Otto and Diesel cycles. Comparison of the mean effective pressures, displacements per horse power and efficiencies of different gas cycles.

(*d*) Properties of vapors, (saturated and superheated steam, ammonia, SO_2, CO_2, ether, mercury, etc.) The development of steam tables, latest investigations on steam and present range of steam table data for saturated and superheated steam. Thermodynamic processes of saturated and superheated vapors including constant pressure, constant volume, constant temperature and adiabatic heat changes; throttling. Entropy diagrams for vapors (T. S.; Mollier). General equations for the flow of vapors.

(*e*) Vapor cycles: The Rankine, the reheating, the regenerative, the reheating-regenerative, and the binary vapor cycles. Mean effective pressure, volume displacement per horsepower and efficiency of different vapor cycles.

(*f*) Compressed air: Work of gas compression. Compression by stages. Volumetric efficiency of compressors. Compressed air motors.

(*g*) Refrigeration: Cycles of refrigerating machines. Refrigeration systems. Coefficient of performance.

4. **The Teaching of Thermodynamics.** A three-hour recitation course for one semester using one or more simple textbooks should enable the average student to gain some general knowledge of the subject. This is ordinarily sufficient for those who do not expect to major in heat engineering. This type of introductory course may be pursued advantageously by all engineering students, although very few institutions require civil, mining and architectural engineering students to study thermodynamics. Students in mechanical and in electrical engineering who are interested in power generation or automotive engineering should follow the introductory course by at least one semester of advanced thermodynamics; in this advanced course considerable attention should be given to thermal processes, heat engine cycles, compressed air, refrigeration and heat transfer.

While lectures at infrequent intervals may be used advan-

tageously in teaching thermodynamics, main reliance should be placed upon recitations and the solution of problems. The accurate solution of problems is very important, but care must be taken not to make the course merely a routine of problem solving. Fundamental principles should be the main aim. Summary lectures near the end of the semester have been found effective.

To broaden the student, he should be familiarized with more than one textbook. Where conditions permit, no two students living together should use the same textbook. In assigning lessons teachers will do well to assign topics rather than refer to specific pages in a textbook.

Engineering thermodynamics lends itself to sectioning and to special rewards for accomplishment. Students should be sectioned in accordance with their records in physics and in mathematics. The superior student should be encouraged to gain a mastery of the subject in less than the normal time by setting up double-pace sections.

Where the subject is taught by more than one teacher, frequent conferences are essential.

Laboratory practice may or may not accompany classroom instruction. Where conditions permit, a three-hour laboratory course should parallel the classroom teaching. Determination of the quality of steam, tests of prime movers, flow of air and similar experiments may be used advantageously in fixing thermodynamic principles and in encouraging the use of the experimental method to demonstrate scientific truths.

5. **Fuels, Combustion and Heat Transfer.**

(*a*) The student should become acquainted with the relative importance of the main energy resources for power production. He should realize that while water power is important, the potential water power of this country which can be developed without expensive storage is less than sixty million horsepower, available about half-time; also while 79 per cent of the power requirements exist east of the Mississippi River, only about 28 per cent of the potential water power is located in that part of the country.

(*b*) A study of fuels should result in definite knowledge of:

The source locality of different fuels, and the fuel resources of the country.

The relative importance of different kinds of solid fuels, the factors which determine their classification and the principles involved in the selection, purchase, analysis and storage of coal.

Coal carbonization and an understanding of the behavior of coal during carbonization, mechanism of coke formation, carbonization processes and the outlet for the by-products of coal carbonization.

Prepared fuels from gasification of coal including producer gas, blast furnace gas and water gas.

Petroleum and its products. Oil fuel for steam generation. Liquid fuels for internal combustion engines. Selection, purchase, analysis and storage of liquid fuels.

Natural gas as fuel.

Prepared liquid fuels including synthetic fuels, alcohols and shale oil.

(*c*) In teaching the principles of combustion, emphasis should be placed upon the importance of thorough mixing of oxygen with the combustible constituents of the fuel; the relation between temperature and good combustion and the time element in combustion calculations.

The student should be taught to make combustion calculations and should have an understanding of how the composition effects the burning qualities of fuels and the relation which exists between carbon dioxide and excess air. He should also be acquainted with the instruments and methods used for analyzing the products of combustion.

(*d*) The use of cooled boiler walls, high steam temperatures, air heaters and other heat absorption equipment in modern power plants are bringing about the necessity for a better appreciation of the problems underlying heat transfer. The student should be able to solve problems involving the transfer of heat by conduction, radiation and convection with particular reference to boiler furnaces. He should also be

able to make heat balance calculations, that is to show the heat in B.T.U. absorbed by the boiler and the losses in flue gases in ash and refuse, in the moisture in the coal, radiation, etc.

6. **The Teaching of Fuels, Combustion and Heat Transfer.** Under proper conditions very little instruction should have to be given in fuels or combustion in connection with courses in heat engineering. Unfortunately, the engineering student completing the required courses in chemistry, knows very little about fuels or combustion calculations. Considerable time must be devoted to these subjects, but care must be taken to base the instruction upon the fundamentals of chemistry.

Instruction in heat transfer may be given either as a part of a course in thermodynamics or in connection with the study of the functional details of power equipment. The study of fuels and of combustion is usually undertaken in connection with the course which deals with the functional details of power plant equipment.

The time to be devoted to this subject varies with the student's preparation and interests. A three-hour course per week for six weeks should enable the student to gain considerable knowledge of fuels and combustion. Students majoring in heat engineering should devote more time.

The recitation method, supplemented by drill in the solution of problems, has been found most effective in teaching fuels, combustion and heat transfer.

7. **Functional Details of Heat Power Equipment.** The student should be familiarized with the following:

(*a*) Fuel Burning Systems. These are to include equipment for handling and for feeding the fuel in proportion to the demand for heat; for supplying air in proportion to the fuel; for heating the mixture of the combustible and air to a temperature above the ignition temperature and for maintaining it at such a temperature until combustion is complete; and for the disposal of any incombustible residue. Hand firing, mechanical stokers, pulverized coal systems, coal and ash handling systems, and equipment for burning oil and gas.

The requirements of a successful fuel burning system should be brought out with special emphasis upon the factors which influence furnace design.

(*b*) Heat absorbing and heat transfer equipment, including boilers, superheaters, economizers, air heaters, reheaters, condensers, evaporators and feed water heaters.

(*c*) Steam generating equipment for small and large plants. Fire tube and water tube boilers; boilers for high pressures; steam accumulators.

(*d*) Steam prime movers with particular emphasis upon steam turbines.

(*e*) Draft producing systems, including stacks and fans.

(*f*) Piping and fittings for steam power plants. Also feed water pumps; circulating, dry and wet air pumps; steam injectors; combustion control and feed water regulating systems; and water purification systems for steam plants.

(*g*) Low-pressure, semi-Diesel and Diesel engines.

(*h*) Gas producers and gas engines.

8. **Economics of Power Generation.**

(*a*) Plant meters. Types essential for the efficient management of a power plant. Registering and recording instruments. Limitations of instruments. Special instruments and meters.

(*b*) Plant records. Types of records and their value.

(*c*) Factors influencing plant design.

(*d*) Factors influencing the cost of power. Relation between fixed charges and operating costs in modern power plants. Obsolescence factor.

(*e*) Cost data of typical modern steam and internal combustion power plants.

9. **Trends in Power Plant Engineering.**

(*a*) Steam pressures and temperatures. Changes during the past 25 years. Maximum practical temperatures. Factors with limit increases in steam temperatures.

(*b*) Sizes of steam plant equipment.

(*c*) Furnace design. Water-cooled and air-cooled furnaces. Volumes for different fuels.

(*d*) Powdered coal versus stokers.

(*e*) Auxiliaries and accessories. Radiant versus convection superheaters; single- and double-pass condensers; preheaters and economizers; combustion control.

(*f*) Plant meters.

(*g*) New cycles.

(*h*) Steam accumulators.

(*i*) Trends in simplification of plant designs. Relation between B.T.U. per unit of power and fixed charges. Obsolescence.

10. **The Teaching of Functional Details and Power Plant Economics.**

A course of three hours per week for one year should enable the engineering student to gain a general knowledge of the functional details of heat power equipment as well as of the economies and of trends in power plant engineering. A briefer one semester course can be developed for civil engineering and for other students not majoring in heat engineering. A three-hour laboratory course per week should parallel classroom instruction and should include performance tests of engines, turbines, boilers, auxiliaries, and complete plants. Every effort should be made to encourage special and original problems both in the laboratory and drafting room. Courses in the design of heat power equipment and of power plants should be offered as electives for seniors and graduates; these should parallel classroom instruction. However, simple design problems should be included in connection with the classroom instruction.

Economics of power generation and trends in lower plant design and operation may be considered only briefly in an introductory course.

Lectures in connection with instruction in heat engineering should be used only for stimulating the student's interest, for summing up the main aims of the course and for pointing out applications. Descriptive lectures, utilizing slides and films, are valuable in broadening the horizon of freshmen and sophomores. A lecture near the end of the course, as mentioned before, may be used advantageously in taking stock of

the fundamental principles which the student is expected to know; also to show the application of such principles. The teacher must, however, always guard against telling a student too much. There is also a tendency for the teacher to talk too much.

The recitation method accompanied by drill in the solution of problems will be found most effective in giving the student grounding in and facility with basic principles of heat engineering. A teacher who is in contact with practice has no difficulty in developing new problems which appeal to the student. Cost figures of actual plants are helpful in developing, on the part of the student, an appreciation of values and costs.

As stated before, laboratory practice should parallel the classroom instruction. For the most effective results the same teacher should conduct both classroom and laboratory instruction. This practice has been found most effective when tried. Unfortunately in most of the larger engineering colleges the older professors consider laboratory instruction something which is below their dignity and which should be handled only by young assistants. The laboratory can be made the medium for illustrating the principles taught in the classroom if the experiments are assigned with due regard to the theoretical instruction. The laboratory gives the teacher an opportunity for close contact with his students such as cannot be had in the classroom.

III. Elective and Graduate Courses in Heat Engineering

Elective courses in heat engineering, three hours per week for one or more semesters, should be available for undergraduate engineering students in the following branches:

1. Steam Power Plant Engineering. Economics, functional and structural details, and trends in power plant design.
2. Thermodynamics. A more advanced course intended to supplement the introductory course given to all engineering students.

3. Internal Combustion Power. Mainly related to stationary gas and oil engine power plants.
4. Automotive Engineering, including the locomotive, automobile, truck, tractor, aeroplane and motorship.
5. Heating and Ventilation.
6. Refrigeration.

Each of the subjects, 1 to 6, may be expanded to cover majors or minors for graduate students. Railway mechanical engineering; power plant engineering; automotive engineering; aeronautics; heating, ventilation and refrigeration are subjects of sufficient breadth to be suitable for advanced study and research in the case of candidates for advanced degrees in mechanical engineering.

11. **The Teaching of Elective and Graduate Courses.** Electives for seniors and graduate students should include special problems or projects in design and research. The objection to the single textbook method is even more important in connection with advanced courses. The project method of instruction should be largely used and each student should be given special assignments which will enable him to apply the fundamentals of heat engineering to the solution of actual problems of considerable magnitude. Students should also be encouraged to work up material in connection with advanced courses which is acceptable for publication in the engineering press. Except in cases of large classes, advanced courses can best be handled through informal conferences betweeen the students and the teacher.

SOME THOUGHTS ON THE TEACHING OF ENGINEERING THERMODYNAMICS*

By GEORGE W. MUNRO

Professor of Thermodynamics, Purdue University

I. Introduction

In considering this subject the teacher should always recognize a double objective; its mental growth or development value, and its engineering tool value.

The first is reflected in the phrase "I try to teach my students to think," while the final examination is considered the ultimate measure of mastery of the subject from a utility standpoint. Ease of measurement too often places the principal emphasis on the second, the teacher too often assuming that a moderate knowledge of the substance of the course presupposes a power of analysis of situations into the appropriate settings. While we usually have to pass our students on a very modest ability to apply proper methods to very carefully simplified problems, the teacher should continually work for situations requiring thought for successful emergence.

Thinking is a curious process and only partly under control. When we try the hardest the results are likely to be *nil,* while sometimes at unexpected moments the desired ideas appear as though from the clouds. But though only partly under control there are certain factors essential for results. If we consider thinking as the production of new ideas from those in stock, we must have; first, a stock, *i.e.,* a body of learned facts or knowledge from which to work; second, language, the universal medium of idea transportation; and finally, time for reflection. I regard these as absolutely essential. The process is then much stimulated by a definite goal—an unsolved problem.

* Presented at the Summer School for Engineering Teachers, Purdue University, July 1, 1929.

As teachers we are charged with providing for these elements which make thought possible. Through textbook, lectures and practice problems we slowly build up a body of knowledge of fundamentals. Through definitions and practice problems, especially the latter, we gradually secure the most essential language tools, and then comes time—over which we have only slight control, even in our own lives.

Time is the very stuff of which life is made. How are we going to insure that the undergraduate student shall have some to devote to reflective thinking? Perhaps no question in education is so little considered as this. Perhaps I am wrong in considering it important, but somehow a college education without an acquired ability to think a problem through; to visualize a situation, assemble and weigh evidence, reason out probable consequences of various actions and finally to make reasonable decisions, is a very superficial assembling of factual information which will be found on examination mostly to belong on the scrapheap. When our alumni and industrialists say that our graduates are no good until they have forgotten everything they learned at college, they doubtless refer to this factual body *necessarily* assembled as a basis for developing thinking ability, and as such indispensable. As technical information it is, of course, museum stuff.

Time to Think. A recent random sampling of one thousand of our students showed 6,699 semester grades, nearly seven subjects taken by each student; seven instructors in a competitive effort to secure each student's attention; seven lines of knowledge being acquired; seven technical vocabularies, each with precision definitions, some with symbols to comprehend, fix and memorize; seven lines of interest for reflective reasoning. Truly, as some one has said, "a student is a person too busy to think." For be it remembered that a modicum of information and of vocabulary *must* be ready for display on demand in each of the seven lines; the alternative is to flunk.

I present the problem of reflective thinking as the next

pressing demand in the progress of engineering education and the heart of that problem is *time to think.*

Mental Growth Values. This involves the *coordination* of facts and laws learned—the *understanding of the subject.* Too often both student and instructor are hazy regarding the place of memory in learning. Without memory we could not learn, yet memorizing is not learning. Illuminating the facts acquired, must be the understanding which relates them to each other and to experience, which is life. So the study of thermodynamics involves securing some knowledge of physics, some knowledge of mathematics and tying them together by comprehension or understanding, so that certain valid relations and conclusions may be secured which were not immediately evident. This finally results in the ability to solve certain classes of problems which may be illustrated by the computation of the temperature resulting from compression of a gas.

The Engineering Tool Value. To secure this necessitates an understanding of the engineering background together with a considerable technical vocabulary and some definitions involving precision in both thought and language. As a tool it must yield correct solutions and here we introduce a supplementary definition of Thermodynamics. *Thermodynamics is the science of solving heat engineering problems to the correct answer.*

Prerequisites. As prerequisites we specify that certain college physics and mathematics shall have been successfully passed. Unfortunately a number of students succeed in passing these subjects without gaining any very clear comprehension of what it is all about, so each division contains a few men whose principal qualification is a Junior assignment card. These men constitute a continual challenge to the instructor finally to clear up every point so he who has never read may understand.

Texts and Source Material. We encourage our students to buy an inexpensive text besides the one regularly assigned. However, because of the confusion in the use of symbols, the undergraduate can hardly be expected to read more than one

text carefully. This is not true of the instructor, who should be familiar with several and who, in his presentations, should avoid, rather than follow, the treatment in the regular text. By doing this the student will be placed in contact with at least two viewpoints, which appears desirable.

The choice of a text for the class is a difficult matter. Usually it is the result of a compromise between fixed conditions and the instructor's ideals. Time available for the work, preparation of the student in prerequisites, work in the heat engineering preceding and subsequent to the treatment of thermodynamic theory, and the instructor's main line of interest aside from thermodynamics, may be mentioned as some influencing factors. There are several very satisfactory texts available.

When the young instructor asks what he shall buy and study that he may have a comprehensive view of his subject in proper perspective, one can be more specific. In case it is not used as the text, my first recommendation is Professor Goodenough's *Principles of Thermodynamics,* edition of 1920, or later. For logical arrangement and rigorous treatment of Engineering Thermodynamics, Professor Goodenough has set a very high standard indeed. The second book I should recommend for buying is Preston's *Theory of Heat;* my own is the 1904 edition. Here, Chapter VIII contains a treatment of thermodynamics without any engineering applications but with a good deal of historical perspective. The 120 pages of this chapter will require a great deal of dilution. It should inspire many trips to the library for less concentrated material. Also, Chapter V, on Change of State, will assist the young instructor to visualize the processes met with in engineering practice. Section VI of this chapter is on the continuity of the state of matter near the critical point, a region now looming large in engineering discussions, while the section on matter supplies the proper discussion on the dynamical theory of gases, and through its historical outline of atomic and molecular theories can be depended on to arouse interest in the modern theories of matter and energy.

II. Teaching Thermodynamics

Turning now from the general to the specific, we consider the basic laws and principles of the subject.

Basic Ideas Likely to be New to the Student.

1. *First Law. When* heat is changed to mechanical energy and *when* mechanical energy is transformed to heat, the ratio is invariable and 1 B.T.U. is equivalent to 778 ft. lbs. of work. Here the emphasis is all placed on the *when,* the energy conservation idea being entirely familiar—it is even considered axiomatic.

Here may be introduced the conception of energy as "high grade" and of partial or incomplete transformation, thus paving the way to Availability and the Second Law.

2. *The Energy Equation*

$$\Delta Q = \Delta u + \Delta W$$

is designated "the first aid to the puzzled," since the engineering set-up frequently shows one of the terms to be zero, thus establishing numerical equality between the other two.

In words, this may be explained: when energy is added to a substance in the form of heat, it will either be absorbed into the molecular energy structure (called intrinsic energy) or will be transformed into external work. This, like the first law, is a special statement of the Law of Conservation of Energy.

3. The idea of intrinsic energy is entirely new to most students and presents more difficulty than any other one conception we present. It has its background in the Kinetic Theory of which third year engineering students have only the haziest idea.

The intrinsic energy equation

$$\Delta u = \Delta K + \Delta P$$

must de developed at length with the focus on the point that ΔK is the change of the *translational* energy of the molecules, which is in turn the element that exchanges energy with the materials of a thermometer and so registers as temperature change. On the other hand ΔP includes all forms of energy

rendered latent in the molecular structure or condition. Particularly, it applies to the potential energy due to overcoming the pull-back of molecules behind, as at the liquid surface during vaporization.

Logic demands that we proceed to develop the ideas of energy as available and unavailable, of entropy as a measure of unavailability and of the Second Law as an integrated conception of the limiting possibilities of transformation of heat to work.

Practically, mental indigestion is reduced by inserting a study of the perfect gas at this point.

The Perfect Gas. All students may be assumed to be familiar with the properties of a gas in a general way, such as the fact that heating or compression tends to raise the temperature and pressure. Few retain from their physics the ability to secure numerical results, so a review, with problems, of the laws of Boyle and Charles is necessary before applying the energy equation to the characteristic equation to develop practical formulae for work, temperature changes, etc.

Here we have our first serious conflict with mathematical incapacity. Any professor of mathematics will concede that a passing grade does not insure competence in every topic, and it would seem as though weakness specialized in exponential equations and logarithms.

What to do? Shall we compel every student to master this development or is exposure, repeated until susceptibility and immunity have been clearly shown throughout the class, sufficient? Every teacher must answer this for himself and assume the responsibility for being wrong—which he is likely to be. Personally, I make the exposure. The better students get the idea as a working background and receive the higher grades; but all must be able to solve typical problems *to correct answers.* It sometimes occurs that the emphasis on correct answers results in non-passing grades in thermo due to inability with logarithms.

Then comes the question, how make the exposure most immediately effective? This is a fundamental question in

teaching methods. How do enough to help the mediocre student without doing too much for the able and independent man? Once a student told me the only fight he ever had in his life was with a boy who insisted on showing him how to do a puzzle. I changed my teaching methods that day. My carefully prepared developments of formulas and carefully worked typical problems are discarded and lost.

Development work is now largely done by mass work at the blackboard. That is, the students are all sent to the board to do the same exercise. When space is limited, the students may work in pairs. Every student now finds himself an independent or a dependent worker; a leader or a trailer. When he copies, he formally recognizes the superiority of another student and the right of the other man to a better grade. Moreover, before he takes work from another student he is imbued with the desire to understand; the will to learn. He will copy my board work in a purely perfunctory way, trusting to future effort to solve its mysteries. His own work at the board is not to be available after the bell rings. Moreover, experience soon shows that it is pointedly prophetic of written test material. Mass blackboard work appears to be very stimulating.

Here, under the properties of gases, we first encounter real language difficulties. The loose popular term heat is largely replaced by the precision terms intrinsic energy, and external work through the energy equation. The process is relatively painless, as the student is ignorant of the event. Then comes isothermal, adiabatic, isovolumic, isopiestic, specific pressure, specific volume, the specific heats and other terms which stand for definite ideas. Lip service in repeating definitions is willingly, even anxiously, rendered. But definitions, howsoever carefully framed, are not ideas. "A *word* is the sign of an *idea*" is the first sentence in my old Harvey Grammar. Many of us stopped right there, leaving an open inference that *any word* may signify *any idea.* So in every class we have a residue, sometimes large, to which language as a precision tool, with words as cutting edges, does not exist. To them, an isothermal is any line which has a gen-

eral resemblance to a toboggan slide. Its appearance on any sheet of paper is a challenge to rope and throw a Naperian Logarithm.

The struggle for ideas at this point is sometimes intense; sometimes pitiful. The first quarry is a choice collection of formulas which seemingly should fit every case. Tragically they get mixed up under amateur care, with dire consequences. The instructor can help but little. He broadcasts the proper ideas through suitable words, the receiver is not properly tuned and only words, not ideas, are registered. Postponement for better receiving conditions is inevitable. During the last ten days of any term my office is filled with students trying to show a belated possession of fundamental ideas, through a series of makeup tests. Frequently contact has been made and the situation is saved.

Joule's Law that the intrinsic energy of a perfect gas depends only on the temperature is a sore puzzle to many students. The mental image of the kinetic structure of a gas, the thermal agitation of the molecules; the rapidity of their motion, their great distances apart, their violent impacts, their elastic rebounds; is simply non-existent to many students. When we divide intrinsic energy into two parts

$$\Delta u = \Delta K + \Delta P$$

and say that, due to the great distance between molecules in a gas, ΔP becomes disappearingly small, we are simply talking fantastic nonsense to these men.

Without this mental picture, Joule's Law and its association of the isothermal and the isoenergic is a pure memory exercise; useful, perhaps, but not in analyzing an engineering situation.

The Air Compressor. The application of the study of the properties of gas to the machine for compressing air can, in a short course, profitably be made immediately. This brings to the student mind the fact that there is wide and immediate use to be made of the theoretical equations with which he has been concerned. Just how much work can be done with com-

pressed air depends on the time available and the background of engineering knowledge possessed by the students.

In our own case, where thermodynamics immediately follows physics, we can assume no background whatever. It is true that most students understand the action of a piston in a cylinder and necessary valve arrangements for inlet and outlet. This widely diffused knowledge is largely due to fifteen million Model T. Fords. While most students do now understand these things, some do not, and this latter group is certain to increase with the increased service station care of automobiles. We, therefore, are obliged to develop the basic action of piston and valves with frequent references to the laboratory for operating examples.

The ideas of compounding engines and multi-staging air compressors are also entirely strange, in fact the steam engine with all its wonderful vocabulary, has passed from the every day experience of our youth. They know about tri-motored airplanes and super-heterodyne radio receivers, but have no idea of the functions of a feed water heater or a condenser. To us, who played around the open boiler room door and whose everyday talk reeked of steam gages, try cocks, Corliss valve gears, steam engine indicators, compound, triple expansion and quadruple expansion engines; of long and short cut-off and throttling and automatic cut off governors; it is inconceivable that some of our students have never been in a steam power plant in their lives nor seen a reciprocating steam engine except on passing locomotives. Power is now distributed. It is turned on by throwing a lever, located on the outside of a locked steel case; where it comes from is the business of the company which owns the electric meter.

What can be done with the air compressor is a question of available time. When thermodynamics was a two-semester course we had time for a very effective practical problem dealing with indicator cards from a two-stage compressor in our own laboratory. With the reduction of alloted time we have had to discontinue this exercise.

The Entropy Idea. The Carnot cycle, available and unavailable energy, entropy and the second law of thermody-

namics are so closely associated that they must be considered, by the teacher at least, as a single learning unit.

Clearly the Carnot engine must introduce the group for it furnishes, not only the basic ideas, but the measuring stick as well. Whether we will then consider available and unavailable energy with Professor Goodenough and secure entropy as a derivative measure of unavailability, or use the heat background as area to develop the temperature-entropy chart depends on personal predilection for analytics or graphics. Personally, the graphical method appeals.

In pursuing this work, use is made of the properties of water—heating the liquid—vaporization—superheating the steam, as this develops the familiar form of the chart used later in the work.

Having developed the chart, the Carnot cycle grows into place with the available and unavailable energy areas clearly in sight. In this connection emphasis is placed on the point that work areas on the entropy-temperature chart are not heat areas but are *holes* in the diagram where heat has disappeared by being converted into work. In this way the slogan that "all heat areas extend to absolute zero" can be emphasized.

The idea of the adiabatic as a vertical line on this chart is natural from the conventions of the diagram. Irreversible adiabatics are not mentioned at this point, that being reserved until the throttling of steam introduces it naturally.

The Second Law. The second law of thermodynamics has not yet been satisfactorily put into words. Various partial statements confuse the student by appearing as self-evident truths; as meaningless collections of words; or, worse yet, as statements having no relation to each other, no meaning in common.

To those informed, it supplies the omission of the first law in failing to indicate *when* transformation from heat to work and from work to heat will take place and how completely.

How confusing to the student the consideration of the second law may be can be appreciated by a careful consideration of the following standard statements, taken from various texts.

Statements of the Second Law. "It is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to another at a higher temperature." *Clausius.*

"It is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of surrounding objects." *Kelvin*

"All reversible engines working between the same source of heat and refrigerator have the same efficiency." *Peabody.*

"Heat had never been known to flow of its own accord from a cold to a relatively hotter body." *Martin.*

"Heat cannot pass from a colder to a warmer body without some compensating transformation taking place." *Bryan.*

"The availability of heat for doing work depends upon its temperature." *Ennis.*

"No change in a system of bodies that can take place of itself can increase the availability of the system." *Goodenough.*

The introduction of the word *availability* in recent years has greatly clarified the meaning of the second law.

Stating the Second Law of Thermodynamics is an innocent pastime in which we all indulge frequently. My own statement has never reached the dignity of appearance in print, but I offer it for any discussion which it may provoke.

The temperature of the source of heat above surrounding objects furnishes a measure of the availability of the heat for conversion into work.

As presented to students this is followed by the following explanatory statement:

As the first law has to do with the *ratio* of thermodynamic transformations, so the second law treats of the *availability* of heat for conversion into mechanical energy. Analogous to this is the case of a water power where the *height above* a *practical discharge level* measures the availability of a source of supply.

Perhaps we may in time cease to try to express in a sentence

a combination of ideas too large adequately to be discussed in a chapter of reasonable length. Certainly we include the natural degradation of energy, available and unavailable energy, reversible and irreversible processes, the elements of the heat engine, the Carnot engine, the ideal efficiency of its cycle, and absolute temperature considered as expression of molecular kinetic energy as fundamental ideas to be recalled by a statement of the second law. Having acquired the ideas the statement may recall them but as a tool of learning it can hardly suggest their existence to one approaching the subject as a novice.

The General Equations. To my mind most undergraduate students do not profit immediately from a study of the general thermodynamic method as developed by Kelvin and modified by various writers. The combination of physics, logic and mathematics is too involved for the very divided attention of the undergraduate student, to whom each of the three elements presents new and unfamiliar fields. Yet every text with any pretence to completeness must include the derivation of a number of general equations.

Unless ample time is allotted to the subject, this work should be omitted from the undergraduate course entirely. Only discouragement can result from a hurried cramming of several pages of meaningless differential equations. In case sufficient time is available, a number of the better students can be interested, since these new methods of attack on physical problems intrigue their imaginations. Still the bulk of the class rely on friend memory to get over the scholastic hurdle set up to trap the negligent. Does this part of the class derive an element of mental growth from the experience at all commensurate with the effort expended? After twenty years it is still an open question with me.

However, the instructor should not neglect to build the background by emphasizing the fact that various properties are dependent on each other and the state of a substance is (except in very special cases) completely determined when two are known. The student accepts as common knowledge that a given amount of a gas at a certain temperature and

under a specified pressure can have only one volume though he may be entirely uncomprehending when you write

$$v = f(p, T).$$

The calculus may be appealed to establish the relation

$$dv = \frac{\partial v}{\partial p} dp + \frac{\partial v}{\partial T} dT,$$

which is a fundamental form in all our work.

The most of our students come to us with little comprehension of independent variables. This should be cleared up if possible in connection with the perfect gases. Use may be made of the whims of Mr. P and Mr. T who can each influence volume independently but neither can establish control.

With these elements of background cleared up the student should later master the general method without difficulty.

GAS CYCLES*

By FRANK O. ELLENWOOD

Professor of Heat Power Engineering, Cornell University

I. The following topics should be studied before cycles:
   Fundamentals regarding energy and its transformation, and the definition of a heat engine.
   First and second laws of thermodynamics.
   Internal energy and heat content (or enthalpy) of any substance in any state: $H = I + APV$.
   The significance of $\int PdV$.
   The simple energy equation: $Q_{1,2} = \Delta I_{1,2} + Wk_{1,2}$
   The energy equation involving specific heat:

$$Q_{1,2} = \int_{T_1}^{T_2} wcdT.$$

   The general equation of steady flow of any fluid.
   Equilibrium and reversibility.
   Entropy.
   The properties of gases.
   Thermodynamic processes of gases.
   The significance of an indicator diagram.

II. Definition of a *cycle* for thermodynamic purposes.
   A *cycle of a working substance* is a series of processes through which the substance passes in order to bring it back to its initial state.
   A *cycle of an engine, turbine or compressor* is the series of processes carried out within the given machine in order to permit the flow of a working substance through it.

* Outline of a lecture delivered at the Summer School for Engineering Teachers, Purdue University, July 1, 1929.

Note: At least the three processes, admission, expansion (or compression), and exhaust, must be involved in such a cycle. The number of revolutions of the mechanism is not a basic factor at all in the definition of its cycle. Thus, the Otto engine may require one or two revolutions per cycle, while the gas or steam turbine may require many revolutions or even less than one for the completion of its cycle. The importance of a clear distinction between the *cycle of the fluid or working substance*, and the *cycle of the engine* can hardly be stressed too much. Engineering literature contains many confusing and inaccurate statements as a result of this laxness. Even worse, however, is the use of the misnomer, "heat cycle," which occasionally appears in print.

III. Kinds of cycles studied by engineers.

Engine, pump, compressor.

(a) Ideal.

(b) Real, including all energy losses.

Working substance, of fluid.

(a) Ideal, with separate organs involving no transfer losses.

(b) Ideal, with a single organ carrying out equivalent processes to give the same net work for the same heat supplied as in (*a*).

(c) Real, with separate organs involving transfer losses.

IV. Factors causing differences between ideal and real cycles.

(1) Leakage.

(2) Friction of the mechanism.

(3) Fluid friction and throttling.

(4) Radiation, heat conduction and convection losses.

(5) Incomplete or delayed combustion.

(6) Improper valve timing.
(7) Working substance.

Note that all of these factors except (7) are directly dependent upon the design, construction, operation and maintenance of the real machine, which must be made with due regard to safety, speed, upkeep and first cost.

V. General method of analysis of a *cycle of a working substance.*

(1) Net $Wk_{cycle} = Q_1 - Q_2 - R_e$ (1)
where Q_1 and Q_2 represent, respectively, the entire amount of *heat supplied to,* and *rejected from,* the fluid during its cycle; and R_e represents the uncontrolled loss of heat from the fluid by radiation, conduction and convection.

Note: Eq. 1 holds for the ideal and real cases but for the ideal $R_e = 0$, and also Q_2 is less than for the corresponding real. Therefore with the same value of Q_1 the net work of the ideal cycle is larger than that of the real.

(2) $T\phi$ diagram to show Q_1, Q_2 and net work of ideal.
(3) PV diagram to show net work of ideal.
(4) Efficiency $= \dfrac{\text{Net Work}}{Q_1}$. (2)

VI. Method of analysis of an ideal *engine cycle.*

(1) Draw the PV diagram to show admission, compression, expansion and exhaust of the fluid passing through the ideal engine.
(2) Calculate the net work done by this fluid in passing through the engine, or $\int VdP$, between the pressure limits of admission and exhaust.
(3) Find the total amount of energy in its various forms supplied to the engine by the fluid, and otherwise.
4) Find the energy rejected (=Energy supplied − Work done).
(5) Find the efficiency

$$\left(= \frac{\text{net work of engine cycle}}{\text{energy supplied to engine}} \right).$$

Note: For the internal combustion motor and the steam power plant the energy supplied is directly measured by the fuel and its heating value, but for any type of steam engine or turbine, considered by itself, the energy supplied is not so calculated.

VII. Example of an analysis of a gas cycle.

(1) Assumptions.

(a) Working substance is an ideal gas.

(b) Steady flow of this substance is maintained by passing through the five machines, *A*, *B*, *C*, *D*, and *E* in series.

(c) The connecting pipes between machines involve no fluid friction or loss of energy by radiation or otherwise.

(d) No free expansion or turbulence takes place in any machine.

(2) Diagrams.

(a) Pressure-Volume, see Fig. 1.

(b) Temperature—Entropy, see Fig. 2.

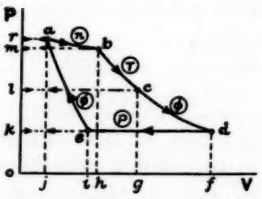


FIG. 1.

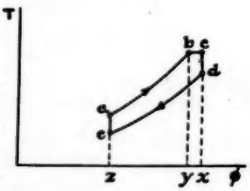


FIG. 2.

(3) Results.

(*a*) Areas showing work done during the *cycle of each machine* are given by the 4th item of Table I.

(*b*) Areas showing work done by the *cycle of the fluid* are given by the 5th and 7th items of Table I.

(*c*) Areas showing Q_1 and Q_2 are given by the 6th item.

(*d*) Efficiency of the *cycle of the fluid*

$$= \frac{\text{area } abcdea \text{ on } T\phi}{\text{area } abcxz}$$

TABLE I

Item No.	The area representing work done by the fluid: during:	MACHINE				
		A	B	C	D	E
1	Admission	*rajo*	*mbho*	*lcgo*	*kdfo*	*keio*
2	Expansion or compression	*abhj*	*bcgh*	*cdfg*	$-deif$	$-eaji$
3	Delivery	$-bmoh$	$-clog$	$-dkof$	$-ekoi$	$-aroj$
4	The cycle of each machine	*rabm*	*mbcl*	*lcdk*	$-kdek = 0$	$-kear$
5	The cycle of the fluid	Net area *abcdea*				

	The area representing the amount of heat transferred to the fluid during:					
6	Expansion or compression	*abyz*	*bcxy*	$cdx = 0$	$-dezx$	$eax = 0$
		$\therefore Q_1 = abcxz$			$\therefore Q_2 = dezx$	
7	The cycle of the fluid	Net area $= Q_1 - Q_2 = abcdea$				

(*e*) Efficiency of the gas cycle *is not* given by the ratio of area *abcdea* to *abcdfja*.

(*f*) If the combined machines in series are *considered as one engine*, the cycle of such an engine becomes the same as the cycle of the fluid because then, and only then, is the fluid returned to its initial state.

(*g*) Advantages to the beginner of seeing how reciprocating apparatus may be displaced by other types of machines, such as the gas turbine and centrifugal compressor.

(4) Comparison with Carnot Cycle.

(*a*) If the processes *abc* and *de* be made isothermals the cycle becomes the Carnot using 4 steady flow machines instead of the classical cylinder usually considered.

(*b*) Efficiency of the Carnot is higher.

(*c*) Net work per unit of piston displacement is greater than that of the Carnot.

VIII. Ideal Otto Cycle.

(1) Processes.

(*a*) 2 constant volume.

(*b*) 2 constant entropy.

(2) Working substances.

(*a*) Cold air (with $\gamma = 1.4$).

(*b*) Hot air (with $\gamma = 1.28\pm$).

(*c*) Real mixture (with γ variable).

(3) Reasons for discarding the cold air standard.

(*a*) It is known to be far from true.

(*b*) The hot air standard is exactly as easy to use and much nearer the truth.

(4) The real mixture standard.

(*a*) Complexities are too great for most undergraduates to study in the short time available.

(*b*) The general principles involved can be briefly discussed, probably with profit to most undergraduates.

(*c*) Debatable points in the calculation still require further study before exact agreement can be expected.

(5) Expression for efficiency of ideal Otto cycle.

(*a*) $e_i = 1 - \frac{1}{r^{(\gamma-1)}}$ (3)

(*b*) Compression *ratio* is involved and not compression *pressure*.

IX. Ideal Diesel Cycle.

(1) Processes.

(*a*) 2 constant entropy.

(*b*) 1 constant pressure.

(*c*) 1 constant volume.

(2) Working substance.

(*a*) Cold air (with $\gamma = 1.4$).

(*b*) Hot air (with $\gamma = 1.35\pm$).

(*c*) Real mixture (with γ variable).

(3) and (4) The same as for the Otto Cycle.

(5) Expression for efficiency of ideal cycle with γ constant.

(*a*) $$e_i = 1 - \frac{1}{r_a^{\gamma-1}}\left[\frac{r_c^{\gamma} - 1}{\gamma(r_c - 1)}\right], \qquad (4)$$

where r_a = compression ratio, and r_c = cut off ratio.

$$r_c = 1 + \frac{L.H.V.}{(1 + W_A + W_B)c_p T_d r_a^{\gamma-1}} \qquad (5)$$

W_A = lb. air per lb. of fuel actually used.

W_B = lb. of residual gas per lb. of fuel.

T_d = abs. temp. at beginning of compression.

X. Comparison of Carnot, Otto, and Diesel ideal cycles.

(1) For the same temperature range.

(2) For the same adiabatic compression ratio.

(3) On the basis of m.e.p.

(4) On the basis of approach by actual engines operating at high speed.

XI. Engine Efficiency.

(1) General definition.

(2) Suitability of the name.

(3) Values of, for modern engines.

THE PROPERTIES OF VAPORS*

By GEORGE W. MUNRO

Professor of Thermodynamics, Purdue University

Strangely, the common properties of vapors are less understood than are those of gases. In spite of some credit in physics and in chemistry, the behavior of water when heated in a closed vessel, or even an open one, has never been closely observed or understood by a considerable part, perhaps even a majority, of our Junior students.

Consequently, we have to begin at the beginnning. The beginning in this instance is that the temperature at which water boils depends on the total pressure to which it is subjected. In the practice of steam engineering this pressure is usually produced by the water vapor, and we are really considering equilibrium, a statement that might as well be made in Greek.

First then, the student must be made to *think* through the equilibrium condition—an exercise he will resist actively. He will willingly learn that $t = f(p)$ only, in any form you desire and then blandly tell you that the boiling point of water is 212° F. Here I try to shock the student by telling him that so far as engineering is concerned the boiling point of water is *never* 212° F. In steam boilers it is much higher, 350° to 600°; in condensers, much lower, 80° to 140°; in cooking vats and heating systems it is somewhat higher, 220° to 240° and in fact a cooling pond is about the only piece of engineering apparatus with the 212° boiling point and that happens never to be used as a boiler.

Then comes the visioning of the water heating-vaporizing-superheating process. This is worth an extra effort, individual with the various students where needful. From it grows

* Presented at the Summer School for Engineering Teachers, Purdue University, July 3, 1929.

our fundamental vapor formulæ such as

$$i_{\text{sup.}} = i' + r + c_p(t_{\text{sup.}} - t_{\text{sat.}}),$$
$$S_m = S' + x\left(\frac{r}{T}\right),$$
$$u_m = u' + x\rho,$$
$$v_m = v' + x(v'' - v').$$

These are quite useless memorized and of course can not be proved—they must be *thought through*. They are fundamental definitions.

The symbols used in connection with the properties of steam are very confusing. For this condition of affairs no one seems to be to blame, least of all the student, yet he is the one to pay the full penalty. The instructor can help some by never using symbols in his talking: saying "intrinsic energy" not I, E or U and "entropy of the liquid" not S', Θ or n. He thus recalls the idea at every using. In developing formulæ, algebraic transformation, etc., he will use the symbols as symbols and as algebraic quantities, but a careful adherence to the rule above, talking in words, not letters, will prove of distinct value to the student.

With the steam tables, enters another idea, new to the minds of many students, that is, the datum or base line; the zero or reference condition. Every one has used it many times, not only in mathematics and physics, formally; but in measuring the height of the window casing or the depth of the water in the swimming tank practically. Yet the looks of blank incomprehension following the statement that the total heat of steam is measured from a condition of liquid ice water indicates that specific knowledge is slow to be generalized.

Steam Tables. On the whole it seems fortunate to have the first contact with the steam tables made in thermodynamics. Where they are used in introductory heat courses a certain facility in "rule of thumb" application may work against a real understanding of their significance later.

The day is past when the undergraduate student can follow the methods of computation through which the various tabulated values were derived. That is a field for experts. How-

ever, the student can and must be made to see the meaning and relationships of the properties of steam as tabulated.

Although it is quite impossible for any but an expert even to follow all the details, the student should be fully informed of the rapid extension of the pressures and temperatures used in power plant practice beyond the limits of our present tables, with the resulting major research project lead by the American Society of Mechanical Engineers whereby the U. S. Bureau of Standards, Harvard University and the Massachusetts Institute of Technology are cooperating with it in determining the properties of steam both saturated and superheated within a pressure temperature field entirely adequate to cover any engineering applications which can now be foreseen and with an accuracy quite sufficient for all engineering applications and for most physical laboratory researches.

As a part of the comprehension of the items in the steam tables, the student must then visualize the process of leading the steam away to a cylinder where the increase of volume as more steam is formed behind pushes the piston forward with a constant pressure, doing work, as in a direct acting steam pump. Assistance in this is sometimes obtained by considering the engine piston as a movable wall of the boiler, the connecting valve (admission valve) being open at the time. An extension of this idea visualizes the cylinder as a part of the condenser when the exhaust valve is open and makes the piston a movable wall of the condenser during the exhaust stroke.

Another device for unifying the steam engine idea is to consider the processes as all carried on in a single vessel on the Carnot engine plan.

Having visualized the heat added and the work done during the formation of steam, the student is then ready to appreciate the great gap between the two values, or the change in intrinsic energy during vaporization (ρ) and its value as a possible source of further work during expansion.

Next we take up the entropy idea, again developing the chart with entropy as width on a heat background. The student is then required to construct such a chart from direc-

tions given. During this period the student is drilled by blackboard exercises in drawing outlines and indicating various sorts of changes such as (*a*) Heating with increasing temperature (heating water), (*b*) Heating with no change of temperature (vaporizing liquid), (*c*) Heating with dropping temperature (expansion of air in air engine cylinder), (*d*) Cooling with rising temperature (air compressor cylinder), and so on. A printed chart (distributed) is also used for solution of numerical problems.

The almost universal use of the entropy temperature chart for the analysis of power plant performance makes it imperative that the student shall have sufficient contact with this diagram to cease to be afraid of it. Having developed it and so having it tamed by familiarity, as it were, we subsequently use it freely and naturally in developing the steam cycles, available and unavailable energy, flow of steam through orifices and nozzles both without and with friction and so on.

With the steam tables and the entropy idea in head and hand we can consider how steam behaves during expansion and compression using the fine logic of the Van der Waals body as a transition step from the simple formulæ of the perfect gas where tables are quite unnecessary, to the extremely complex behavior of superheated steam where the engineer must have the services of specialists in mathematics and in physics to furnish the required numerical values in tabular form.

During the discussion of the steam tables the subject of the critical state is sure to come up almost always with some reference to Andrew's work with carbon dioxide. Here reference is given to the Chapter V, Section VI, "On the Continuity of State" in Preston's *Theory of Heat*. Nearly every class has one or two students interested enough to borrow the book and read that very fascinating chapter.

After problems in determining final condition, heat change and work done for various changes of state have been solved, the Rankine cycle as a modification of the Carnot cycle is introduced. This reintroduces the idea of work of the cycle as differing from the work done during a single process. With it also come the basic ideas of heat drop or change in thermal

potential or heat content. Thermal potential $(u + pv)$ is much to be preferred as having a precision of meaning difficult to secure in connection with the word heat.

Afterward, the heat-entropy diagram can be introduced for the solution of problems in steam cycles. This diagram is so simple to use in getting the answer that care must be taken that the student does not get it too early and side-step the rational solution of problems.

The introduction of the present trends in steam pressures and temperatures; turbine bleeding for heating and process work and the new steam plant cycles involving reheating and regenerative processes is developed both in lecture and in problem work. While a goodly number of our students get the underlying ideas, a significant minority frankly do not know what it is all about. With them understanding must wait on additional contacts with heat engineering subjects in class, laboratory and in field.

Nor is this lack of understanding to be considered strange. In the short period of six weeks we conduct students absolutely without background in the properties or use of steam, through the nature and relations of steam properties as tabulated; the arrangement and scope of the steam tables; the meaning and construction of entropy diagrams; the behavior of steam under heating, cooling, expansion and compression; the ideal Rankine cycle; its practical modification to apply it to both reciprocating and turbine engine cycles; the factors underlying power plant trends, and the new cycles devised to make the most effective use of the new knowledge of steam and its properties. Not only do we desire comprehension of these things but we insist that knowledge shall be so specific and well in hand that engineering situations may be correctly analyzed and correct numerical answers to problems growing out of such situations be rendered. Perhaps if we could look back from five to thirty five years into our own sophomoric mind a better appreciation of student handicaps would result.

Be it remembered, also, that these students have on the average 6.7 *other* subjects demanding plain and fancy study

before any entirely personal program of exercise, recreation, reading and activities can be attempted.

For Improved Teaching

It seems as though the subject of teaching Thermodynamics should not be concluded without some suggestion looking to the betterment of instruction in the subject.

This improvement must come through improving our instructors. The obvious way of going out and hiring older and more experienced men to teach the subject might work for a single institution but always at the expense of other institutions no less in need. Rather we need some agency to expedite the ripening or maturing process in instructors: something to enlarge their teaching horizons rapidly, that the fool blunders may be mostly over in the first three years instead of appearing with disturbing regularity over twenty years as in my own experience.

We recruit our teaching staffs mostly from our own graduates or from graduates of neighboring schools where as students they usually have ranked in the upper third of their classes; seldom in the highest tenth. Two years helping in a laboratory while working for a Master's degree, largely through regularly prescribed courses, scarcely alters their undergraduate viewpoint of educational problems.

Placed in charge of a class these men are fundamentally lacking in both the knowledge of their subject and of the underlying principles of learning and teaching. We have all been in this predicament and we have all somehow "muddled through," or part way through.

What agencies, I ask, can be set up which will appreciably reduce the "muddling?"

Summer session courses are at once expensive and ineffective. Few young engineering instructors can afford to devote the time or the money to attend them. Then too, the courses offered are elementary, given mostly for undergraduates of the lowest type—flunkers. Usually, also, they are given by instructors not yet through "muddling" themselves.

To meet this need I suggest a short course, preferably given at the end of the summer vacation, of about five days. A lecture by an experienced teacher each morning (8–9) on some fundamental topic, followed by three hours (9–12) individual study, questions, and small group discussions with the instructor present to assist and consult as needed. Afternoons and evenings open for recreation, sightseeing and contemplative thought.

The central thought in providing such a conference would be that it should be for instructors with *less* than five years teaching experience and so it must come within both the *time* and *financial* budgets of such men. The group should contain from fifteen to thirty and would need a room with blackboard and desks or drawing tables. The leader should be able to project some ideas in a lecture and be willing to stay on with the group until the ideas have been assimulated through study, problem work and discussion.

To give concreteness to the proposal consider the possibilities in the following five topics, each to constitute a four-hour project:

1. Fundamental conceptions (heat, intrinsic energy, work, kinetic theory of heat) and the properties of gases including air compressors.
2. Reversibility, the Carnot engine, availability and the Second Law.
3. Entropy and the development of some general equations.
4. Properties of Vapors and Steam Cycles.
5. Flow of fluids, the steam turbine and steam injectors.

We have short courses for bankers, engine operators, gas meter repairmen, welders, plumbers and laundrymen but nowhere is there now provided a corresponding short intense period of instruction available to the young engineering teacher.

My conception of the central purpose of the S. P. E. E. Summer School for Teachers is to point the way to precisely the sort of teacher training conferences just outlined.

VAPOR CYCLES*

By FRANK O. ELLENWOOD

Professor of Heat Power Engineering, Cornell University

I. Prerequisites.
  (1) All of that previously given for gas cycles.
  (2) Properties of vapors and liquids.
    (*a*) Saturated and non-saturated liquids.
    (*b*) Saturated and superheated vapors.
    (*c*) Mixture of vapor and liquid.
  (3) Vapor tables.
  (4) PV and $T\phi$ diagrams.
  (5) Comparison of different vapors and liquids.
  (6) Thermodynamic processes of vapors and liquids.
  (7) Vapor charts.

II. Distinction between engine and vapor cycle.
  (See Section II, outline of lecture on Gas Cycles)

III. Carnot vapor cycle.
  (1) For power plants.
    (*a*) With a single organ.
    (*b*) With 4 organs; boiler, engine condenser and pump.
  (2) For refrigeration plants.

IV. Significance of $(\Delta H)_\phi$ for *any substance.*
  (1) Conditions that are to be fulfilled.
    (*a*) No change in velocity, or $v_1 = v_2$.
    (*b*) No change in elevation, or $z_1 = z_2$.
    (*c*) No transfer of heat to or from the fluid in passing from container No. 1 to container No. 2.

* Outline of a lecture delivered at the Summer School for Engineering Teachers, July 3, 1929.

(*d*) p_1 is a constant pressure maintained in container No. 1.

(*e*) p_2 is a different constant pressure maintained in container No. 2.

(2) Results, if p_1 is greater than p_2 and $\phi_1 = \phi_2$.

(*a*) $h_1 - h_2$ represents the *maximum work obtainable from a unit weight of* the given fluid in flowing from container No. 1 into container No. 2.

(*b*) $h_1 - h_2$ represents the *minimum work that must be expended upon a unit weight of the given fluid* to force it from container No. 2 into container No. 1.

(*c*) $h_1 - h_2 = -\int_{p_1}^{p_2} VdP$ = area *l12k* in Fig. 1.

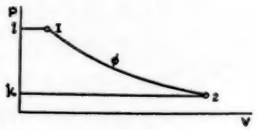


FIG. 1.

(3) Examples.

(*a*) Any type of ideal engine having complete expansion without reheating or extraction of fluid.

(*b*) Any type of ideal compressor, or pump, without cooling devices of any kind.

V. Turbulence and fluid friction.

(1) Effect of, on turbine performance.

(a) Increases the specific volume, entropy, and heat content at exhaust.

(*b*) Makes the *energy obtainable from a given flow* of fluid through a real machine *less* than $(\Delta H)_\phi$.

(2) Effect of, on pump or compressor.

(*a*) Same as 1(*a*).

(*b*) Makes the energy required to produce a given flow of fluid through a real machine *greater than* $(\Delta H)_\phi$.

VI. Rankine *engine cycle.*

(1) Apparatus = ideal engine having complete expansion.

(2) Processes.

(*a*) constant pressure admission, as *la* in Fig. 2 (*a*).

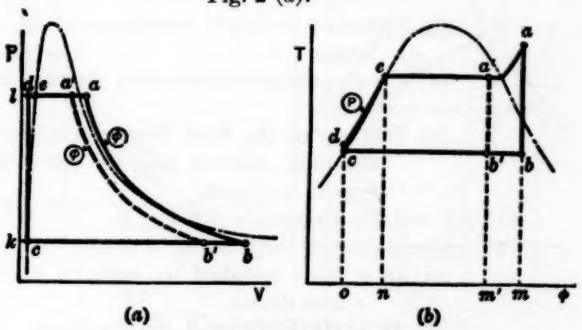


FIG. 2. The Rankine Vapor Cycle.

(*b*) constant entropy expansion, *ab.*

(*c*) constant pressure exhaust, *bk.*

(3) Energy supplied per pound of fluid = $h_a - h_e$, where h_e = heat content of saturated liquid at exhaust pressure.

(4) Energy rejected per pound of fluid = $h_b - h_e$.

(5) Work done per pound of fluid in passing through the Rankine engine = $h_a - h_b$ = exact area *labk.* See *PV* diagram of Fig. 2.

= approximate area *deabcd* of Fig. 2(*a*) and (*b*).

(6) Efficiency $= \dfrac{h_a - h_b}{h_a - h_e}$. (1*a*)

(7) A standard.

(*a*) For turbines having no reheating or bleeding.

(*b*) For reciprocating engines, without reheating or bleeding.

VII. Rankine *vapor cycle.*

(1) Apparatus, ideal. Rankine engine, condenser, boiler feed pump and piping.

(2) Processes.

(*a*) Isentropic expansion *ab* in engine.

(*b*) Constant pressure condensation, *bc*, in condenser.

(*c*) Constant entropy compression, *cd*, in pump.

(*d*) Constant pressure formation of steam, *dea*, in boiler.

(*e*) Delivery of the fluid from one organ to the next, without gain or loss of energy in any form.

(3) PV and $T\phi$ diagrams. See Fig. 2.

(4) Analysis of cycle for 1 pound of fluid.

(*a*) Q_1 = Heat supplied by boiler = $h_a - h_d$ = area *deamo*.

(*b*) Q_2 = Heat absorbed by condenser = $h_b - h_c$ = area *bcom*.

(*c*) $Q_1 - Q_2$ = Net work of the vapor cycle = $(h_a - h_b) - (h_d - h_c)$ = area *abcdea* exactly.

(*d*) E = Work done *by fluid* in passing through the engine, = $h_a - h_b$ = area *labk*.

(*e*) F = Work done *upon the fluid* in passing through the feed pump, = $h_d - h_c$ = area *kcdl*.

(*f*) $E - F$ = Net work of the vapor cycle = $(h_a - h_b) - (h_d - h_c)$ = area *abcdea*. (See (*c*) above.)

(*g*) Efficiency of vapor cycle $= \dfrac{Q_1 - Q_2}{Q_1}$

$$= \frac{(h_a - h_b) - (h_d - h_c)}{h_a - h_d}$$

$$= \frac{h_a - h_b - F}{h_a - h_c - F}. \qquad (1b)$$

VIII. Non-expansion cycle.

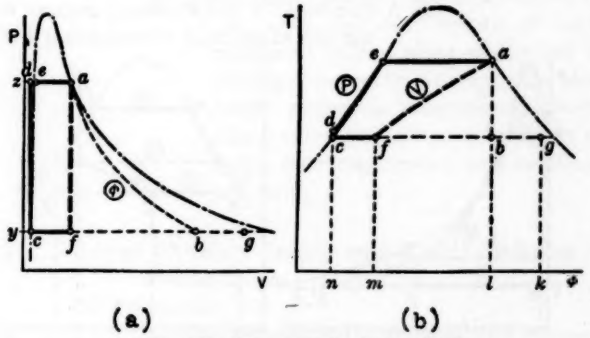
(1) *Engine.*

(*a*) PV diagram, *zafy* in Fig. 3.

(*b*) Wk. of cycle $= A(P_a - P_f)V_a$ B.t.u. per lb.

(*c*) Energy supplied $= h_{\text{throttle}} - h_{\text{ex.p.}} = h_a - h_c$.

(*d*) Efficiency $= \dfrac{A(P_a - P_f)\overline{V}_a}{h_a - h_c}$. (2*a*)



(a) (b)

FIG. 3. The Non-expansion Vapor Cycle.

(2) *Vapor.*

(*a*) PV and $T\phi$ diagrams *deafcd* in Fig. 3.

(*b*) Net Wk. $= A(P_a - P_f)V_a - F$, B.t.u. per lb.

(*c*) $Q_1 = Q_{dea}$ = area *dealnd* $= h_a - h_d$.

(*d*) $Q_2 = Q_{cfa}$ = area *cfalnc* $= (h_f - h_c) + (i_a - i_f)$.

(*e*) $Q_1 - Q_2$ = net Wk. = area *cdeaf*.

(*f*) Efficiency

$$= \frac{A(P_a - P_f)\overline{V}_a - F}{h_a - h_d, \quad \text{or} \quad h_a - h_c - F}. \qquad (2b)$$

(*g*) "Equivalent state," *g*, for constant pressure condensation after free expansion.

Note.—This state represented by *g* is such that if the vapor were exhausted from the engine at the constant pressure p_g, the same amount of heat would be rejected as with the processes *af* and *fc*.

IX. Incomplete expansion cycle.

(1) *Engine.*

(*a*) *PV* diagram, *zabfy* in Fig. 4.

(*b*) Combination of Rankine and non-expansion.

(*c*) Efficiency

$$= \frac{h_a - h_b + A(P_b - P_f)\overline{V}_b}{h_a - h_c} \qquad (3a)$$

(*d*) A standard for reciprocating engines having the same ratio of expansion V_b/V_a.

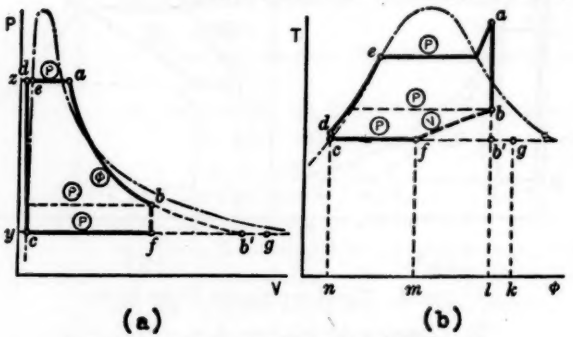


FIG. 4. The Incomplete Expansion Vapor Cycle.

(2) *Vapor.*

(*a*) *PV* and $T\phi$ diagrams, *deafbcd* in Vig. 4.

(*b*) Efficiency $= \dfrac{\text{Net Wk.}}{Q_1}$

$$= \frac{h_a - h_b + A(P_b - P_f)\overline{V}_b - F}{h_a - h_c - F} \qquad (3b)$$

X. Reheating Cycle.

(1) Reasons for reheating.

(2) Methods of reheating.

(3) Losses in reheating system.

(4) Ideal engine cycle.

(*a*) Without losses in reheating system.

(*b*) With the same losses in the reheating

system as in the actual case; a fair standard for measuring performance of a turbine independent of reheating piping.

(5) Ideal vapor cycle.

(*a*) Complete circuit made without any loss due to throttling, leakage, friction, or heat transfer.

(*b*) A suitable standard for comparison of the net work per unit weight of vapor circulated in real plant which has the following items the same as in the ideal: boiler pressure, temperature leaving superheater and reheater, pressure entering reheating system, and condenser pressure.

XI. Analysis of *ideal reheating engine cycle* involving reheating losses.

(1) Processes.

(*a*) The same throttle pressure and temperature as in the actual case.

(*b*) Admission at throttle pressure and temperature.

(*c*) Isentropic expansion to the same pressure as that at which the vapor enters the actual reheating system.

(*d*) After reheating, the vapor is returned to the turbine at the *same pressure* and *temperature* as in the actual case.

(*e*) Isentropic expansion to the same pressure as in the actual condenser.

(*f*) Exhaust at condenser pressure.

(2) PV and $T\phi$ diagrams, see Fig. 5.

(3) Work done in B.t.u. per pound of vapor passing through this engine = area $(labk + jdei) = h_a - h_b + h_d - h_e$. (4)

(4) Energy supplied to engine $= h_a - h_c + h_d - h_b$ (5)

(5) Efficiency $= \dfrac{h_a - h_b + h_d - h_e}{h_a - h_c + h_d - h_b}$. (6)

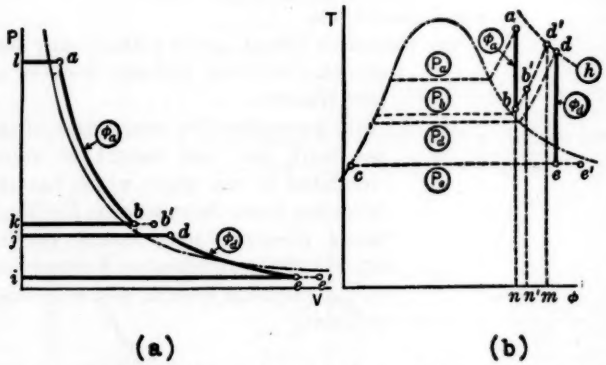


FIG. 5. The Ideal Reheating Engine Cycle Involving Reheating Losses.

XII. Performance of *actual reheating engine.*

(1) Energy supplied $= h_a - h_c + h_d - h_{b'}$. (7)

(2) Brake thermal efficiency

$$= \frac{2545}{w_b(h_a - h_c + h_d - h_{b'})}. \quad (8)$$

(w_b = lb. of steam actually used per b.hp.hr.)

(3) Brake engine efficiency

$$= \frac{w_i(h_a - h_c + h_d - h_b)}{w_b(h_a - h_c + h_d - h_{b'})}. \quad (9)$$

(w_i = lb. of steam per hp.hr. by ideal engine.)

Note: It is important to observe that, due to imperfections in the real turbine, $h_{b'}$ will always be appreciably larger than h_b; consequently the brake engine efficiency cannot be found by the ratio of w_i to w_b, alone.

XIII. *Regenerative vapor cycle.*

(1) With an infinite number of heaters.

(*a*) An ideal that may be approached fairly closely with relatively a small number of heaters.

(*b*) A convenient standard for making a series of calculations regarding power plant performance for wide ranges of pressure and temperature. (See Transactions A.S.M.E., 1923, p. 644 to 823.)

(*c*) Cycle efficiency increases rapidly with the pressure, from 200 to 1200 lb. per sq. inch.

(2) With a finite number of heaters.

(*a*) The number of heaters commonly found to be commercially feasible to install varies from 1 to 4.

(*b*) The higher the throttle pressure, the larger the number of heaters installed generally.

(*c*) The most important cycle in large steam power plants using high pressure today.

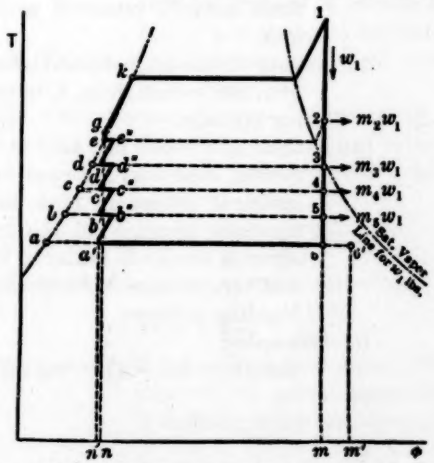


FIG. 6. The Regenerative Vapor Cycle.

XIV. Analysis of an *ideal regenerative vapor cycle with a finite* number of *heaters.*

(1) Temperature-entropy diagram.

(*a*) See Fig. 6, where 1 represents the state of w_1 pounds of steam leaving the boiler at the same pressure and temperature as in the actual case; m_2, m_3, m_4, and m_5 represent the respective fractions of w_1 that are bled at the various points.

(*b*) Location of the saturated liquid lines for reduced weights.

$$\frac{\phi_2 - \phi_e''}{\phi_2 - \phi_e} = \frac{1 - m_2}{1}, \quad \text{and} \quad \frac{\phi_3 - \phi_d''}{\phi_3 - \phi_d} = \frac{1 - m_2 - m_3}{1}, \quad \text{etc.}$$

(*c*) Advantages of this method of construction as contrasted with many other forms.

(2) Finding the amount of steam bled at each point of the ideal cycle.

(*a*) Consider the same number of heaters as in the actual case.

(*b*) Choose the same bleeding pressures as those actually observed with the real unit.

(*c*) Assume the steam to expand isentropically from the known state, 1, to each bleeding pressure.

(*d*) Assume no losses of any kind in the heater system, and that for each heater just sufficient steam is bled to heat at constant pressure all the feed water entering the given heater to the saturation temperature corresponding to the bleeding pressure.

(*e*) Examples:

$$m_2 w_1(h_2 - h_e) - (1 - m_2)w_1(h_e - h_d)$$

or

$$m_2 = \frac{h_e - h_d}{h_2 - h_a}. \qquad (10a)$$

$$m_5 w_1(h_5 - h_b) = (1 - m_2 - m_3 - m_4 - m_5) w_1(h_b - h_a),$$

or

$$m_5 = \frac{(1 - m_2 - m_3 - m_4)(h_b - h_2)}{h_5 - h_a}. \qquad (10b)$$

(3) Heat supplied and net work per pound of steam flowing from the boiler.

(*a*) Q_1 = area $gklmng = h_1 - h_g = h_1 - h_e - F$ (11)

(*b*) Net work = area bounded by heavy lines in Fig. 6 $= h_1 - h_6 - m_2(h_2 - h_6) - m_3(h_3 - h_6) - m_4(h_4 - h_6) - m_5(h_5 - h_6) - F$, where F = work of ideal pumps. (12)

(4) Efficiency $= \dfrac{\text{Net Work}}{Q_1}$. (13)

XV. Ideal *regenerative engine cycle* with a finite number of heaters.

(1) The state of the steam at the entrance to the turbine, instead of at the exit of the boiler, is now chosen for state 1, Fig. 6.

(2) Energy supplied per pound of throttle flow $= h_1 - h_e$. (14)

(3) Available energy, or work done, per lb. of throttle flow, $Wk_i = h_1 - h_6 - m_2(h_2 - h_6) - m_3(h_3 - h_6) - m_4(h_4 - h_6) - m_5(h_5 - h_6)$. (15)

(4) Efficiency $= \dfrac{\text{Available energy}}{h_1 - h_e}$. (16)

(5) Ideal steam rate of regenerative unit, in lb. per kw.hr., $= w_i = \dfrac{3413}{Wk_i}$. (17)

(6) A standard with which to compare the performance of the actual regenerative unit, (consisting of the turbine-generator and

heaters) which requires w_a lb. of steam per kw. hr. and which gives a feed water temperature, t_f, leaving the last heater.

(*a*) Combined thermal efficiency of actual unit $= \dfrac{3413}{w_a(h_1 - h_f)}$. (18)

(*b*) Combined engine efficiency of actual unit

$$= \frac{\text{Energy supplied ideal unit per kw. hr.}}{\text{Energy supplied actual unit per kw. hr.}} = \frac{w_i(h_i - h_e)}{w_a(h_1 - h_f)}. \quad (19)$$

Note: It is important to observe from this last equation that the ratio of steam rates alone will not give the engine efficiency of this unit, because the temperature of the feed water in the real unit, t_f, is less than t_e for the corresponding ideal.

FUELS AND COMBUSTION *

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Mechanical engineering in one of its phases may be defined as that branch of engineering which deals with the utilization of our natural energy resources. This definition thus involves, as the principal raw materials, fuels and water. In this sense it is necessary to view the whole of our energy resources in a broad way so that the proper importance may be attached to any one type.

In this paper coal is discussed as the most essential of our energy resources, first, from the point of view of its relation to other energy resources; second, from the point of view of its importance as a storehouse of valuable constituents possible of reclamation; and third, from the point of view of the combustion engineer. The mechanical engineer dealing with coal will as a rule be concerned primarily with the last phase of this discussion.

Coal as an Energy Resource. In 1926 about 70 per cent of the total energy developed for utilization in one form or another in the industry of this country had as its source coal. If the figures are extended to include the whole world we find that more than 75 per cent of the utilized energy was furnished by coal, 16 per cent by oil and gas and less than 9 per cent by water power. These are the figures reported in a recent publication of the Bureau of Mines entitled "Coal in 1926." Thus coal is today and will remain for a long time to come our most important resource of energy.

We have, of course, large natural resources in the form of petroleum and water power. However large our oil resources it is quite certain that compared to our great supplies of easily

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obtainable coal, the so obtainable oil supplies are small. They should therefore be reserved for use in generating power and heat in those cases where coal may not be conveniently used.

Of the water powers still undeveloped the largest are situated in regions where they will be of little use to mankind for many years to come. Canada, notably in the provinces of Quebec and Ontario, still has some large potential hydraulic resources. Some of these may be developed in the not distant future. The greatest concentrations of such undeveloped resources are located south of the Equator. In Belgian Congo estimates place the resources at 90 million horsepower and in Brazil at 25 million horsepower.

The total installed primary power, excluding the automobile, is in the United States probably something over one-half of the sum of the last two figures; in 1918 it was estimated at 42 million horsepower. Today the installed central station power alone is about equal to this, of which some 12 million horsepower is hydraulic. The Geological Survey estimates that approximately 35 million horsepower of our potential hydraulic resources is still available for development. Most of this, however, is located in the Rocky Mountain and Pacific Coast regions, whereas the major increase in load may be looked for in the region east of the Rocky Mountains.

Of the potential water powers in this country much will cost above 250 dollars per kw. of installed capacity to develop, which means that it would in most such cases be possible to generate power for the same localities at less expense in central stations burning coal. The economics of the case seem to show that when the cost of a hydraulic installation is more than 200 dollars per kw. it is in general cheaper to use coal as the source of energy. The capacity factor has of course an important bearing on this condition, as the higher this is the larger may be the initial investment for a given cost of power.

Coal as a Storehouse of Valuable Materials. As this art is now developed the processing of coal may be considered in the following four major divisions :

1. High temperature carbonization of coal.
2. Complete gasification of coal :Producer and Blue water gas.

3. Low temperature carbonization of coal.
4. Hydrogenation of coal.

In all of these the purpose of the process is to yield fuels or other materials in either the solid, liquid or gaseous states, having thus a higher form value than that possessed by the coal matter as mined.

The so-called high temperature carbonization industry is one of the world's oldest and dates back to the time when wood was first carbonized to smelt bronze. It was the smelting of ores which gave the initial impetus to this industry and in this country, even today, there would be comparatively little carbonization of coal if it were not for the large demand for metallurgical coke by the steel industry. Over 80 per cent of all the coke produced in one way or another is used by the steel mills in their blast furnaces. It is the best fuel for smelting which can be produced economically in large quantities.

The records of the Geological Survey show that in 1880 the industry reported 186 plants with over 12,000 beehive ovens, carbonizing over 5,000,000 tons of coal and producing over 3,000,000 tons of coke annually, the only product, and having a value of about $6,600,000. From such small beginnings the industry has grown until in 1926, 82 million tons of coal were carbonized, mainly in the high temperature type of by-product oven, and the total value of the products, including coke, tar, ammonium sulphate, etc., was about one-half billion dollars. The city gas industry, although carbonizing but a small fraction of the total coal carbonized, sell their gas in a higher-priced market and so bring the value of all products from coal carbonization up to nearly one billion dollars annually.

This large increase in value of the products of carbonization is the result of, first, the increased quantity of coal that is carbonized and, second, the replacement of the crude beehive type of oven, from which the only product was coke, with the by-product oven which yields the products mentioned above. It is estimated that by 1933 there will be practically no beehive ovens in existence.

In spite of the large value of the products from this source,

only about 15 per cent of our total coal output is processed in this way. i.e., high temperature carbonization, the other 85 per cent being burned as a raw fuel To date there have been in this country no installations on a commercial scale of either the low temperature coal carbonization or coal hydrogenation processes which have proven beyond doubt that they are successful. We are not yet sure that they will pay dividends.

In the low as distinguished from the high temperature carbonization process, the temperature within the retort is maintained at a lower level in order to prevent cracking down of some of the hydro-carbons. Under these conditions a more volatile coke is yielded and in the by-products more tar and light oils are reclaimed. There is less gas but of a higher heating value and the ammonium sulphate output is lower.

This process has attracted a large amount of attention in England and Germany because it promised there to increase the yield of motor spirits. There the price of gasolene, which must be imported, is very much higher than it is in this country. In England there is also a good domestic market for the low temperature type of coke which burns more easily and with a larger flame than does the firmer high temperature coke. It is burned there in open fireplaces, of which many are used as the sole means of heating and in which the Englishman likes to see the play of the flame. These conditions seemed to offer a good opportunity for the development of the low temperature carbonization process and investigations have been supported for the past ten years by the British Government under the direction of Dr. C. H. Lander. As a result there are in operation today several plants, one of which at least has a capacity of 200 tons of output in coke per day. It is too soon to say whether or not these plants will pay dividends.

The most notable example of the coal hydrogenation process is perhaps that developed by Dr. Bergius in Germany. It has as its object the conversion of a considerable fraction of the coal matter into oil. It is to be noted that oil is now the chief product of the treatment, whereas in the various coal distillation processes which have been discussed it was only one

of several by-products and coke or gas, depending upon the treatment, were the chief products.

In Berginisation the difference between the hydrogen content of coal and oil is introduced by having the coal mass at a high pressure and temperature. Of his process Bergius says, in his paper presented before the first international coal conference held at the Carnegie Institute in Pittsburgh, November, 1926:

> "I need not say that this study has involved a very complicated research. From the beginning I realized that I had taken on an enormous task. But looking at the oil-supply problem from the European side, the burden was inevitable. . . .
>
> "We realized soon that liquefaction of coal involves more or less a competition between two reactions—the reaction of hydrogen addition to the coal substance, and the reaction of destructive distillation of coal. Within a certain range of temperature the velocity of hydrogenation reaction is greater than the velocity of the coking reaction. At higher temperatures the coking reaction is faster and results finally in the formation of coke instead of oil, even if hydrogen pressure is high and hydrogen is brought into the closest possible contact with the coal.
>
> "The hydrogenation of coal begins at relatively low temperatures. Treated for some hours at a temperature of 300–350° C. the product is still solid, but it has taken up a fairly large amount of hydrogen, and is transformed into a sort of pitch with a fairly high melting point. This product becomes liquid if treatment is continued at a temperature of about 450° C.
>
> "From these facts it is readily understood that the coal liquefaction reaction process, regarded from the chemical standpoint, consists of two different reactions: the first, hydrogen addition, and the second, the splitting up of large molecules into smaller ones while new hydrogen is added.
>
> "This second reaction involves the very same procedure as the splitting-off of heavy oil residues of tars at low temperatures in the presence of hydrogen under pressure, a process which has been carried through by us on a large scale. In other words, it is a cracking process in which hydrogen is absorbed. By changing the conditions, the relation between gases, light and heavy products can be varied.
>
> "From the foregoing you see that coal-liquefaction represents the sum of a complicated system of various chemical reactions to which the laws of normal organic chemistry are not easily applicable.
>
> "Hydrogen enters the comparatively large molecular complex. The higher the temperature, the more the larger molecules are

broken up into smaller ones, to which the hydrogen is added, thereby changing the unsaturated smaller molecules into saturated ones.

"Beginning with methane and extending up to the highest hydrocarbon compounds typical representatives of the aliphatic, aromatic and hydro-aromatic series are in the coal liquefaction products, except of course, the unsaturated compounds which cannot be formed in the presence of high-pressure hydrogen. Besides these chemical compounds those of phenolic character, chiefly cresol, and ammonia, are among the products. Very difficult and complicated research work was necessary to obtain these results, involving extended experiments with high-pressure apparatus, exact heating and temperature control and special analytical methods.

"Only a few years ago, after the period in which we had already made thousands of experiments, articles were still being published which denied the possibility of coal-hydrogenation. It is only within a very recent time that the chemical possibility of coal liquefaction has been generally recognized. The opinion was expressed at the time that our coal liquefaction reaction was no more than a low-temperature distillation of special coals. By comparing two simple experiments, made under the very same conditions, one with hydrogen, the other with nitrogen, under pressure, we proved this opinion wrong."

You will note that Bergius mentions the oil-supply problem from the European side. Briefly this problem is this. The ratio of inhabitants to oil supply is enormously larger for Europe than it is for America. This oil supply for Europe is contained in Galicia, Rumania and Russia and since the war the large increase in local consumption of these oil fields has forced the shutting off from France and Germany at least of a large part of this supply. Oil prices in the French and German markets have thus advanced to very high levels, making it seem feasible to develop a system, even at great expense, by means of which oil could be produced in quantity from the only locally available raw material for it, namely, coal.

Thus it is seen that the economic situation both as to low temperature processing and hydrogenation of coal is far different in this country from that existing in Europe. We have large supplies of natural oil, limited supplies of anthracite and very large supplies of excellent bituminous coal. A coal treating process which might pay good dividends in Europe

may still involve far too large an expense for successful operation in this country.

Combustion of Coal in Boiler Furnaces, Past and Present. As early as 1702 Thomas Savery published a pamphlet entitled "The Miner's Friend; or an Engine to Raise Water by Fire." Quoting from this concerning his furnaces we have the following:

> "Your furnace must be so contrived that your flames take a turn or two round each of the boilers which any bricklayer used to furnaces can do: it being performed by a row of bricks round them like a skrew or worm, which being contiguous to the wall of the Furnaces and the Boilers makes as it were a worm funnel round them both, from whence you may continue your chimney."
>
> . . . . . .
>
> "The coal used in this engine is of little value, as coals commonly burnt on the mouths of coal-pits are; for an engine of a three-inch bore or thereabouts, working the water up sixty feet high, requires a fireplace not above twenty inches deep and fourteen or fifteen inches wide, which will occasion so small a consumption, that in a coal-pit it is of no account, as we have experienced."

These quotations illustrate the almost complete ignorance which existed then concerning the nature of combustion. The main objective of furnace proportioning was obviously so to arrange the unit as to get the greatest amount of energy as heat transferred into the water. That such procedure interfered with the progress of combustion probably never occurred to Savery, or if it did it was not considered of any importance. Coal was literally as cheap as dirt and probably regarded as in much the same category.

Watt in 1785 took out a patent on what amounted to a furnace designed to burn coal with less smoke. Watt probably gave some thought to the combustion efficiency of his furnace but his chief objective was to avoid the smoke nuisance. The striking fact is that this same attitude of mind has persisted concerning improvements in boiler furnaces at least until after the middle of the nineteenth century and not until in the early nineteen hundreds was any serious attempt made to discover how such furnaces should be proportioned in order to provide conditions under which the combustion re-

action may progress to completion when at the same time the rate of energy release is high.

Today a single boiler furnace of such size as to generate steam in sufficient quantity for power generation at the rate of 200,000 horsepower is just over the horizon. In such a furnace 100 million B.T.U. would be released per hour. Five such furnaces would be sufficient to supply the steam for peak load power equivalent to which could be supplied 90 per cent of the time, by utilization of the total potential water powers of New England, and ten would suffice to supply the peak power which could be supplied 50 per cent of the time. Thirty such furnaces would be sufficient to supply the steam for power equivalent to that which could be developed by the total potential water powers of New York State. This includes Niagara fully developed and a large part of the possible St. Lawrence River water power.

This stupendous increase in the output which may be obtained from a single furnace probably had its beginning in this country with the investigations carried on by the Bureau of Mines in the fields of combustion and heat transfer. In 1912 Kreisinger and Ray published some of these results in Bulletin No. 18 entitled "The Transmission of Heat into Steam Boilers." It was shown here that the heat absorbing surfaces of the boiler as then arranged were being operated at rates of heat transfer far below the safe limits. In 1917 Kreisinger, Augustine and Ovitz published as Bulletin No. 135 of the Bureau of Mines their studies entitled "Combustion of Coal and Design of Boiler Furnaces." In this investigation the progress of the reaction for coals burned on a grate was studied. Recently Mr. A. C. Fieldner of this Bureau has been considering a study of the same nature for pulverized coal firing. This work may be under way now.

The Combustion Reaction. Let us now consider in a little more detail the process which goes on in a furnace and which is called combustion. What are the broad underlying principles which may be made use of, for instance in an attempt to evaluate what is really occurring here? From what angle shall we view such a process? Is a statement, if such

were possible, of the chemical reactions which occur, sufficient to define it; or, are there some other factors of equal or greater influence in controlling its progress towards what we know as complete combustion?

Concerning the last question, a little reflection will show that the reaction itself may occur only after the oxygen and combustible constituents have been put in touch with each other. The time required for the reaction after contact between the reacting molecules has once been established is, for most of the constituents, except at low temperatures, exceedingly small compared to that required to bring them together. The factors controlling the rate at which energy is released in a furnace are thus, not the reaction velocities, but instead those forces which drive the oxygen and fuel constituents from place to place within the burning mixture.

Diffusion may play an important part here. As an example, consider for a moment low velocity air and gas streams sandwiched in between each other as they issue in parallel streams from a burner into a furnace. Diffusion is almost the sole force which is driving the gas and oxygen molecules towards each other and by computations based on the diffusion rates and flow velocities, a close approximation to the flame length may be determined if the individual gas and air streams are not too thick. Obviously, the thinner each stream is the shorter the flame for a given velocity of flow, because it will take less time for the molecules to diffuse the shorter distances.

As a second example consider a carbon particle in a pulverized coal furnace. This particle is moving continuously from within an envelope of inert gases and products of combustion. The thickness of this envelope or film depends on the scrubbing action of the layers of gases sweeping around the particle but any oxygen coming from the outside toward the particle must in the last stage of its journey diffuse through this surface film. It is seen that the forces due to the turbulent motion of the gases play, in such cases, an important part in the rate of combustion. Thus turbulence provides another force which the combustion engineer makes use of. The extent of the carbon surfaces per unit weight of fuel, *i.e.*, fineness of

grinding, is another dimension which must be taken into account in such cases. This is a surface reaction.

In a fuel bed on a grate through which air is forced under pressure the turbulence is so high at the fuel surfaces as to reduce the surface of film thickness to such small dimensions as to result in a combustion rate proportional to the air flow. It is impossible, if there are no holes in the fuel bed, to drive air through it at a sufficient rate to have any of the oxygen appear at the surface uncombined with what was combustible matter. Turbulence and diffusion are thus the chief factors in determining the time that will be required to complete combustion in the industrial furnace. The extent of the exposed fuel furnace here is of only secondary importance.

Unfortunately, turbulence is very difficult to provide for just where it is needed most. This is in the end or burning-out zone of the flame. Both theory and experience show that 80 to 90 per cent of the combustion of pulverized coal for instance may be completed in the first 10 to 20 per cent of the space provided for completing combustion. Therefore, 80 to 90 per cent of the furnace volume must be provided to burn out the last 10 to 20 per cent of the combustible matter. This is partly because in general the turbulence is dying out rapidly along the flame path. It is the only force that could be made use of in order to utilize the last part of the furnace volume more efficiently without introducing excessive amounts of air in the end zone of the flame.

The factors which enter into the rate at which energy is released in, say, a cubic foot of furnace space are

1. The quantity of combustible in this space ..... F
2. The quantity of free oxygen in this space ..... O
3. The quantity of inert gases in this space I
4. The diffusion and turbulence factor ..... D
5. The temperature of the mixture ..... T

In terms of these quantities the rate of combustion is approximately proportional to the quantity

$$\frac{F \cdot O \cdot D}{(F + O + I)} \cdot (T)^{1/n},$$

where (n) is perhaps a constant. Obviously, as the mixture travels along the flame path the numerator of this expression is a rapidly decreasing quantity, and the denominator remains constant in values. Unless this decrease in the values of the product $F \cdot O$ in the numerator may be made up for by an increase in the value of the turbulence factor D, the rate of energy release per cubic foot of space rapidly decreases along the flame path. But under the usual conditions of firing this factor likewise decreases towards the end of the flame with the results before noted.

Taking such a relation as the starting point, neglecting for the moment the influence of temperature and considering the case of just the theoretical oxygen supply, it becomes possible by integration to develop an expression showing the relation of distance traveled or time elapsed to the completeness of combustion. This expression for gaseous fuels is shown by the following equation:

$$t\Big|_1^2 = C_1 \frac{1}{D \cdot F}\Big|_1^2,$$

where C_1 is a constant involving the fuel characteristics, etc.

Inspection of this equation shows that if the turbulence factor D is doubled, the time required in order to attain any state of the progress of the combustion is proportionately decreased. Therefore flame length is proportionately decreased, other conditions remaining the same.

The equation also shows that the time required for complete combustion ($F_2 =$ zero) is infinite, which is true for just theoretical oxygen requirements because the chance that the last oxygen molecule finds the last fuel molecule is infinitesimally small unless the turbulence factor should be infinitely large.

Obviously an increase in the oxygen supply over theoretical requirements will result in a steeper slope to curves plotted between time t and unburned combustible fraction F, particularly for the smaller fractions unburned, and under these conditions the curves would not extend to infinity but would

intersect the t axis at some definite point whose distance out would be controlled by the amount of excess oxygen present. Thus is shown the influence of turbulence and excess oxygen on furnace volume requirements.

Temperature always plays an important part in the progress of the early stages of the reaction, but in a different way. Assuming that air is provided in sufficient quantity at all stages of the process, the reaction itself will proceed as above explained if the temperature is high enough so that it may occur at all. The total distance of flame travel obviously includes that required to bring the constituents up to the ignition temperature. To provide for an early ignition the arrangements should be such as to raise quickly the temperature of the incoming mixture to the ignition points of those constituents which should be burned completely as soon as oxygen is supplied to them. As an example, a deficiency of oxygen or too low a temperature in the early stages of the reaction may result in throwing out finely divided carbon in the form of soot. This occurs under such conditions in coal-fired furnaces during the distillation period when heavy hydro-carbons are discharged in the form of tar vapors which are broken down into soot, light hydro-carbons and other light combustible gases. The lighter gases burn first, the soot remaining in suspension as very tiny particles of incandescent carbon which give the flame its luminosity. In some cases a luminous flame may be desired but where it is merely a question of having the total energy released with least losses a clear flame is usually sought after. With most high volatile coals this can only be accomplished if special provisions are made for bringing the mixture up to ignition temperatures quickly and in the presence of sufficient oxygen and when in addition to this the mixture is in a state of violent turbulence. Preheating the air for combustion is also very beneficial under these circumstances.

During the progress of the reaction it is within a continuously changing atmosphere and the fuel constituents themselves are continuously changing. The state of chemical

equilibrium toward which the reactions of the several components are driving are themselves shifting and for some of the constituents the reaction may actually reverse itself several times. An example is the reaction between carbon and the oxygen in a fuel bed where, in the lower zones, carbon dioxide is formed but as this travels up through the fuel bed the equilibrium between the extended carbon surfaces, oxygen and carbon dioxide is such at the higher temperature existing there that a reduction of the carbon dioxide to carbon monoxide occurs. The rate of the reaction in this reversed direction is controlled in this case by the velocity of the chemical reaction rather than by the rate of diffusion because the former is now the slower speed process. Likewise, during the early stages of volatile distillation the reactions of some of the constituents thrown out may undergo several reversals of direction. To some extent, as shown for the case of soot formation, the direction of such reactions may be controlled.

Along with evolution of energy as heat in the course of the reaction, there are transfers of energy by radiation, conduction, diffusion and convection between the parts of the mixture, from the mixture to the furnace walls and from the furnace walls to the zones of the flame at the lower temperature.

The available knowledge of the details of that which is going on here is very incomplete. We know only in a few scattered cases just what the exact controlling factors of intermediate reactions during and immediately following volatile distillation are. Indeed, we do not even know the exact character of these volatile constituents before they are discharged from the coal matter itself.

In the matter of transfer of energy between the several parts of the furnace there is also much information still to be obtained. We are not sure of our radiation constants and even the laws of radiation, particularly with reference to the gaseous constituents and ultra-minute solid particles of coal matter and ash have not been worked out, at least to the complete satisfaction of the scientist. It is thus apparent that in the present state of our knowledge it is not possible to work

out by any analytical method the progress of the reaction step by step toward completion. But it is interesting to speculate for a moment on the information which might be obtained if this were done.

Such an analysis would show us the exact state of the mixture at every stage of the development of the process. It would show us also the preferred direction of the process in each step and how it could be controlled so that the preferred reactions should occur. It would show us the exact rate at which energy is being released in each part of the flame and also the exact rates at which energy as heat is being transferred between the various parts of the flame and between the flame parts and the furnace walls. It would thus enable a determination of temperatures at all points. Finally it would show how much it is possible to increase the rates of energy release by increasing, for instance, such a factor as turbulence and just how a furnace should have its several parts arranged in order to bring this about in practice.

The preceding paragraph is perhaps a generalized statement of some things that are desirable in the combustion investigations: it is the answers to the questions which these statements bring to mind which are at the very root of the combustion problem. Indeed, Dr. Rosin of Freiburg, Germany, has made an attempt to attack the problem from this angle and although his solution for such variables as, for instance, the maximum possible rate of energy release, is based on only fragmentary evidence of what may be the actual facts, it is still a step in the right direction. His paper on this subject entitled "A Thermodynamic Basis of Pulverized Coal Combustion" was presented at the Second International Conference on Bituminous Coal held in Pittsburgh last November.

Bringing Together the Known Facts. Out of this confusing mass of, for the most part, indefinite information what is there that the combustion engineer may lay his hands on? What general principles may be of value in arriving at quantitative results? Let us begin here by examining the data which is included in the ultimate and proximate analyses of a fuel such as coal. I will assume now that of a particular coal

you have the ultimate and proximate analyses and perhaps the calorific value. This information at least may be furnished by any good fuel chemist. The question is, how much information do you now have concerning the real character of this coal? With this at hand you will be able to fit the coal into some system of classification so that you will know at least of what rank it is. You will have a name for it such as bituminous, semi-bituminous, etc. You will have sufficient information also to determine how much air should be used in burning it and what the final analysis of the products of combustion should look like if made. The analysis of the products of combustion will enable you to plot a curve showing the relation between the temperature of the products of combustion and the thermal capacity of the products per pound of coal. This curve, if plotted from data accurately evaluated from our best specific heat equations for the several constituents, is an exceedingly useful one because it shows exactly between any two temperatures how much energy as heat must be added or abstracted in accomplishing the change. It represents certainly the curve along which the products must be cooled if combustion is completed before the gaseous mixture enters a cooling zone such as the convection zone of a boiler. To sum up, you now have sufficient data to determine the possible amount of energy release, the air supply and the cooling process. You also know the rank of the coal and how much volatile matter will be discharged in the combustion process. This is about the sum total of the information to be obtained by reference only to the coal analyses, and heating values.

Such behavior characteristics as coke formation, free-burning, how the ash behaves, how hard it is to grind the coal for pulverization and other properties, a knowledge of which is often essential to even a reasonably good estimate of the coal as a fuel for a certain purpose are not evident from the coal analysis. In fact, in these respects an ultimate analysis yields just about as much information as it does to say of a house that it is 50 per cent stone, 30 per cent wood, 10 per cent glass, 5 per cent mortar and 5 per cent iron. The real char-

acter of the house is revealed only to the extent of enabling one to classify it as what might be called a stone house. The particular way in which the various elements are built in together is not shown and this is of more significance concerning the real character of the house than is the mere quantitative statement of the various constituents

Unfortunately, our knowledge of the behavior characteristics of coal is not yet so organized that generally recognized formal tests of one kind or another on samples are available for the unquestioned determination of these various properties. We have tentative tests for determination of the coking properties, the determination of the reactivity of the coke that is formed, for the determination of the fusing temperature of the ash, . . . etc., and in the event of nothing better available such tests are performed. There is always the question however, if in a large scale process in a possibly different atmosphere the coal and ash will behave as they have under the conditions of test of a sample. In the last analysis where large quantities of coal are involved the best trial is always one under conditions approaching operation as nearly as possible.

The engineer may thus look upon the usual data furnished him by the fuel chemist as merely a tool by means of which he can determine the final products of the reaction. The reaction itself will progress to these final products only if the conditions are right. The engineer must therefore think more in such terms as turbulence, diffusion, and surface, provided for the reaction to occur at, as in the case of pulverized coal firing, than has been his custom in the past.

Having provided for the right storm in the furnace atmosphere, he may, in further analyzing the process, apply the principle of conservation of energy to it. Obviously, the energy residual in the fuel to start with and that brought in with the air are distributed at any stage of the process between energy still in the fuel, energy present as sensible and latent heats in the furnace gases, and energy which has been transferred to the furnace walls.

In addition to the above, it is within the province of the

engineer to design the various parts of the furnace so that operation is accomplished with the greatest ease consistent with low maintenance costs. This phase of the problem involves as examples means for proper treatment of the fuel bed so that air may flow through it in correct quantities at the right places and so that the ash is properly disposed of. It involves also the use of correct materials in the proper proportions in the furnace walls so that these may be maintained at low cost. It may in some cases involve provisions for absorption of a considerable amount of energy as heat in the furnace walls. This in itself is a difficult study and cannot be further discussed in this lecture.

In conclusion it might be said, that although combustion when viewed in the light of the more elementary reactions appears as a rather simple process, it is in fact a succession of very complex transformations and involves not only the chemical reaction but also, to a far greater extent, such other factors as turbulence, diffusion, rate of heating flame parts, fineness of grinding, air distribution, etc., which are necessary to make it possible for the reaction to occur at all. The combustion engineer of the future may profit by searching in other fields, such as carbonization of coal, for needed information which apparently is lacking now. Many of the problems in the several fields rest for solutions on the same basic principles. We are gradually gathering together some of the fragments and hope one fine day to have a complete picture. A thoroughly organized program for investigation will, when carried through, place the industries involved on a higher scientific level, and if we do not progress in this way now it may be necessary for us to struggle desperately in an attempt to make up for lost time in the not too distant future. Certainly when our oil resources begin to show real signs of depletion that day will have arrived. The door to some of the secrets has been opened a little at least, and what can be seen through that opening looks very promising for the future.

REPORT OF CONFERENCE ON MECHANICS AT OHIO STATE UNIVERSITY

June 22–26, 1929

Following the annual meeting of the S. P. E. E. at Columbus, Ohio, June, 1929, a four-day Conference on Mechanics was held in the form of a series of round table discussions. Nearly forty persons attended the sessions on the first day of the conference, and about twenty-five the subsequent days.

There was no uniform daily program, but the sessions were generally arranged about as follows. Two ninety-minute sessions were held in the forenoon, separated by an intermission of twenty or thirty minutes. In the afternoon, beginning about two o'clock, one similar session was held, and another beginning about seven-thirty, occupied the evening.

No formal program was followed, but those present determined what questions should be taken up. The usual procedure was for some member to open a session with a ten- or twenty-minute discussion of a topic in which he was particularly interested. Each one present then had an opportunity to give his views on the points brought out. Particular effort was made to deal with one point at a time and to concentrate the discussion on a single question until it had been sufficiently treated. Much of the discussion was in the form of question and answers. Participation was general on the part of all present. Often it was so eager and animated that from 30 to 40 different persons would speak in an hour. Before the close of each session, the topic to be taken up at the opening of the following session was decided upon.

Most of the questions included in the tentative program published in the JOURNAL for February, 1929, were taken up, or at least touched upon. No attempt was made to harmonize

divergent views, but rather to bring out clearly opposing opinions as to the theory and practice of teaching mechanics.

It seemed to be the opinion of a majority of those present that only a minor part of the emphasis and effort in the study of mechanics should go to the memorizing of definitions, laws, and demonstrations; that a much greater part of the time should be devoted to practice in the application of the fundamentals to practical problems; and that considerable time be devoted to details of computation, mathematical form, and procedure. There was, however, much divergence in opinions as to how best to handle the details of numerical computation.

There was general agreement that graphical methods should occupy only a minor place in the first course in mechanics. There was great interest in comparing methods in vogue at the various institutions in preparing and giving preliminary and final examinations. The proportion of failures in the various courses in mechanics at different places also received much attention.

A. P. Poorman presented in detail the latest studies of class room methods by the standing committee on mechanics. E. W. Rettger, J. E. Boyd and E. R. Maurer discussed interestingly methods of introducing class room experiments into the elementary courses in mechanics, and S. Timoshenko explained the recently introduced advanced courses in mechanics at the University of Michigan. It is hoped that a complete summary of the discussions may be prepared for publication at a later date.

The following is a list, by institutions, of those attending one or more of the sessions and participating in the discussions:

Brooklyn Polytechnic Institute—L. F. Rader.
Carnegie Institute of Technology—N. C. Riggs; M. M. Frocht
Clemson College—Leroy Tucker.
Columbia University—George B. Pegram.
Cornell University—E. W. Rettger; W. Rodney Cornell.
Dayton University—F. C. Hartwick.
International Combustion Engineering Corporation—William De Baufre.

Iowa University—Sherman M. Woodward.
Kansas State College—E. R. Dawley.
Maine University—Charles P. Weston.
Marshall College (W. Va.)—A. T. Bragonier.
Michigan University—Wendell M. Coates; S. Timoshenko; C. T. Olmstead.
Minnesota University—George C. Priester; W. E. Brooke.
North Carolina State College—L. E. Wooten.
Ohio State University—J. E. Boyd; P. W. Ott; S. B. Folk; R. W. Powell; E. F. Coddington.
Princeton University—F. L. Eidmann.
Purdue University—A. P. Poorman; R. G. Dukes; H. F. Girvin.
Rochester University—W. J. Conley.
Rutgers University—H. Lea Mason; Floyd E. Mehrhof.
Toledo University—J. B. Brandeberry.
Virginia Polytechnic Institute—L. O'Shaughnessy.
Washington University (Seattle)—E. R. Wilcox.
West Virginia University—H. G. Neal.
Wisconsin University—E. R. Maurer; M. O. Withey.
Worcester Polytechnic Institute—Gleason MacCullough.

REPORT OF COMMITTEE ON MECHANICS *

As a part of the program of the Annual Meeting of S. P. E. E. held at Chapel Hill, N. C., in June, 1928, your Committee on Mechanics arranged two sessions at which some of the questions concerning the teaching of Mechanics were discussed. As an outgrowth of these two short sessions and also of the Summer School for Teachers of Mechanics held at the University of Wisconsin, and at Cornell University, in 1927, a five-day conference on Mechanics has been planned for 1929. This conference will be held here at Columbus immediately following this Annual Meeting, and will last from Saturday, June 22, to Thursday, June 27. A Committee on Arrangements, with Professor S. M. Woodward as Chairman, was appointed last year and an interesting program has been prepared. Any of the members of S. P. E. E. who are interested in questions relating to the teaching of Mechanics are invited to remain for this conference. It will close in time for the opening of the S. P. E. E. Summer School for Teachers of Mechanical Engineering at Purdue.

Partly in preparation for this Conference and partly as an independent project, your Committee on Mechanics has also made a study of the following questions:

1. What are the advantages and disadvantages of conducting a course in Mechanics by the lecture method, without a text book or printed notes?

2. What are the advantages and disadvantages of conducting a course in Mechanics by the use of assigned problems, with library references to a number of books for the underlying theory?

3. What are the advantages and disadvantages of conducting a course in Mechanics by the use of mimeographed notes, examples and problems, prepared by the instructor and furnished to the students?

* Presented at the 37th annual meeting of the Society, Ohio State University, June 19–22, 1929.

4. What are the advantages and disadvantages of conducting a course in Mechanics by the use of some standard text book?

5. In the light of your own teaching experience, what advice in regard to his undergraduate course would you give a student who intends to prepare to teach Mechanics? Would you advise any post-graduate work in addition? Any normal school work? Any courses in psychology?

6. Should the young instructor in Mechanics be urged to take up some line of research? Will the research, in itself, add to the value of a teacher to his students?

7. From the standpoint of good teaching, would it be advisable for a young instructor to alternate for a few years between teaching and practical work?

Time will permit only a brief synopsis of the discussion elicited by these questions. The complete discussion is appended to this report and is made a part of it for publication.

1. The lecture method is good for the instructor but wastes the students' time.

2. Problems with library references will work well with advanced students and with small groups, but is cumbersome and inefficient with the average class.

3. Mimeographed notes permit a freedom in treatment not possible with a text book, but involve a large amount of labor. As a book for later reference, such notes are unattractive.

4. The textbook method is considered the most effective, as the student has his material in good shape for future reference. As disadvantages, problems may become stale and solutions generally available for anyone who wishes to copy them.

5. Only occasionally, do students consciously prepare for teaching Mechanics. An engineering course, with a wide variety of engineering problems is highly desirable. Advanced work in Physics and Mechanics is valuable. Normal school training is considered worthless. There is no unanimity as to the value of courses in psychology.

6. Original research, properly conducted by one interested in the subject being investigated will add to the teacher's

equipment, but care must be taken that this narrow field of research is not given an undue amount of space and time in the year's work.

7. Alternate periods of teaching and of practical experience are eminently desirable, but summer work appears to be the most practical solution.

Respectfully submitted,

G. P. BOOMSLITER,
J. E. BOYD,
W. S. FRANKLIN,
S. G. GEORGE,
C. E. PAUL,
S. M. WOODWARD,
A. P. POORMAN, *Chairman.*

ITEMS FOR STUDY BY COMMITTEE ON MECHANICS FOR THE MEETING OF JUNE, 1929

1. What are the advantages and disadvantages of conducting a course in Mechanics by the lecture method, without a textbook or printed notes?

Prof. G. P. Boomsliter.—The advantages of the lecture system are that the instructor develops a subject from his own point of view and therefore his presentation may be fresher and more vigorous than if it followed a text book or a prescribed outline. On the other hand he is likely to stress his hobbies and neglect fundamentals unless he is very careful. There are several other decided disadvantages to this system however. First, the student in general is a poor taker of notes. In mechanics this will be intensified by the fact that he must generally follow the reasoning of the lecturer which he cannot do if he must pause and give his attention to the act of writing in the middle of such a listening process. Second, he will not in general be in a position to recall effectively what he has obtained previously because his notes even if well taken do not as attractively and clearly present the subject as would a well written, illustrated text book. Third, the instructor will rarely cover the required subject matter in a course in mechanics. The time given to this subject is too short to discuss, clarify and apply fully all of the necessary subjects in any course in the allotted time.

Prof. J. E. Boyd.—Lecture system is a waste of time. Not suitable for a mathematical subject. Notes not sufficiently accurate for study and review. Would have to be supplemented by neostyled problems.

Prof. S. G. George.—Without going into detailed reasons for the opinions expressed by the writer, he may be permitted to give the results of an experience of more than twenty years of teaching mechanics. This statement will apply to the seven items presented by the Chairman of Committee No. 27.

The advantages appear to be that the instructor is able to arrange the order of topics presented, the scope or emphasis laid upon each topic, and to extend or rearrange the material as the individual classes or groups of students may require. For an experienced instructor, this method of conducting a course is convenient.

The disadvantages are many. Students are not provided with any material to study in advance, nor with any well arranged material for later study and review. Their notes obtained at the lectures are likely to be inadequate, poorly arranged, and in no form for future use in study or as reference material. Inexperienced instructors will find the method very burdensome. Classes will not be uniformly dealt with, and will not cover the same ground. Individual students are not likely to have their difficulties with the subject explained. The general trend of instruction in the subject of Mechanics is toward more individual instruction, and away from the lecture method.

Prof. C. E. Paul.—I believe that there are very distinct disadvantages in connection with the attempt to conduct a course in Mechanics by the lecture method, without a textbook or some form of prepared notes. I do not believe that the students are of an age where they have the ability to distinguish between the lesser and the more important items which should be put into a series of notes during the lecture. Again, the element of time devoted to the subject is not sufficient so that the student can form his own textbook as he proceeds in the course. Nor do I believe that the average student in the second year of college work has become sufficiently alert that he can follow the details of a lecture on such a subject and digest the material at the rate at which it is fed to him by an instructor who has his subject well in hand.

The distinct advantage of the lecture method of instruction is not apparent to me.

Prof. A. P. Poorman.—For the experienced instructor, the lecture method of teaching mechanics has the advantage that a more intimate and thorough mastery of the subject matter of the lesson is required on the part of the instructor, with a consequent radiation of enthusiasm to his students, especially if illustrative problems are attacked together. For its effective use, classes should be small, and student ability should be high.

If classes are large, individual contacts are necessarily few and

the mediocre or poor student gets little, either of knowledge or inspiration. If the student attempts to take notes, some important explanation may be lost.

2. What are the advantages and disadvantages of conducting a course in Mechanics by use of assigned problems, with library references to a number of textbooks for the underlying theory?

Prof. G. P. Boomsliter.—The second proposed method is one which would appeal to many educators as developing initiative, resourcefulness and a broad view point, but to my mind it has several serious disadvantages. In the first place it presupposes a well stocked library with several copies of many texts. Secondly, the ordinary student will be confused by the variation in nomenclature to be found in the different text books. Thirdly, he will be compelled to devote much more time to a course than is ordinarily possible in our curricula which assumes eighteen to twenty hours of work per semester, each hour to require two hours of preparation. This means from fifty-four to sixty hours per week, considerably more than union hours. This might work well with the first quarter of a class but not with those of fair ability or less.

Prof. J. E. Boyd.—May be a good system for advanced work for a small class, if the library facilities are sufficient to avoid loss of time waiting for books. Neostyled references and problems are necessary.

Prof. S. G. George.—If there is advantage in a unique way of conducting a course, this method would have that merit. It might fit a small institution but not a large one. It might also lead to individual contact with each student and would offer the instructor opportunities to discuss and to clarify individual difficulties. Students would get a certain valuable familiarity with the group of texts used as references, and this would be an unusual occurrence. Personally the writer has never tried this method with elementary classes, but only with advanced students. With such students the results are satisfactory. If the younger students can be made to take an interest in the literature of Mechanics, and to become really acquainted with the classical texts and with the best of the present day books, they have a familiar source of information for problems to be met later.

This method of conducting classes in Mechanics has many disadvantages, in the opinion of the writer, far outweighing its advantages. The method is cumbersome and awkward in the extreme. It requires too much time and labor of instructors and of students. It involves complications in notation alone that would condemn it. Texts are not easily made available in numbers and at times convenient for student reference. If strong emphasis is laid upon the solution of problems done outside of class and under

little supervision, other disadvantages appear. The instructors have no assurance that the solutions are the result of a student's unaided effort, and a poor basis for grading a student's work is presented. Sometimes, in the vicinity of large institutions, such solutions are made by persons who call themselves tutors, and make their living by this kind of parasitism.

Prof. C. E. Paul.—My opinion in regard to Item No. 2 is very similar to that expressed in regard to Item No. 1. The value of assigned problems with library references is most apparent where a student has an abundance of time to give to the subject. Then, I believe that a very distinct advantage is found in this method. Such plans are likely to be burdensome to the student where he has the small amount of time allowed at present by the credit-hour plan of arranging college courses. I believe that a slow, or weak student might be tempted to abandon individual effort where he was pushed for time and seek the aid of his classmate, or even duplicate their work if pushed to extreme need.

Prof. A. P. Poorman.—For advanced or second year work in Mechanics, or for elementary work with small classes of high grade students, the method of using printed lists of problems and library references is highly desirable. Individual talent and ability is much more easily recognized. For the poor or even the average student, the difference in symbols used by different authors is very confusing. This difficulty has been overcome to some extent in recent years through the efforts of Committee No. 20 on Standardization of Technical Nomenclature, but the results of former years still persist.

3. What are the advantages and disadvantages of conducting a course in Mechanics by the use of mimeographed notes, examples and problems prepared by the instructor and furnished to students?

Prof. G. P. Boomsliter.—If mimeographed notes are to be considered, why not use a text book in the first place which usually is easier to read, is better illustrated and is more carefully edited and proof read. I have never yet seen a list of mimeographed problems which did not contain some and usually many errors.

Prof. J. E. Boyd.—Neostyled notes are equivalent to a text book. Not so easy to handle and read nor so well illustrated. If good, should be printed. Such notes may well be used to supplement a textbook or to give subjects which are not satisfactorily discussed in the text. We use neostyled assignments and some auxiliary problems with the text book. These are changed each quarter.

Prof. S. G. George.—With this procedure the writer has had considerable experience. The advantages are as follows:

It gives opportunity for freedom in treatment of different topics.

It allows of rapid change, and the speedy elimination of topics to suit changes in other courses.

It makes the treatment of a subject individual to the school in which it is used, and, being favored there, is likely to be taught with more lively interest.

On the other hand, the disadvantages are:

It is a constant burden upon one or more instructors to see that a current supply is available.

The appearance can not be made so legible, so attractive, so well emphasized by style of print and character of illustration as a modern printed book. Students do not care for such notes as they would care for an attractively bound book, and the notes are not preserved for later reference as a book would be. Even if kept, mimeographed notes are bulky, they deteriorate, and they do not fit into an engineering library.

To fill out a course so as to give more emphasis to certain topics, notes are a valuable aid. Likewise in the development of a new text.

Prof. C. E. Paul.—I am in favor of the use of mimeographed notes, examples and problems, or of the use of a textbook as mentioned in Item No. 4. I believe that the plans outlined in Items Nos. 3 and 4 are the most efficient for use in ordinary class instruction. I further believe that the mimeographed notes or text book should be used as a means of studying basic principles outside of the class room. The problem work in connection with the text should change from year to year, as I have found that copies of problems of previous years and their solutions are frequently kept by groups of students and passed on to the men of the next year. This difficulty can be overcome easily by an instructor if he assigns new problems each year over a period of one college generation. After that, old problems can be reassigned to the classes which follow over similar periods.

Prof. A. P. Poorman.—If the instructor's load is light enough so that he can afford the time to prepare mimeographed notes, examples and problems, this method of getting the material before his students may be made very effective. The instructor can put his own personality into the material, he can rearrange the order of various parts if it is thought desirable and he can keep his material up to date by the addition of problems relating to engineering work which may be in progress in the vicinity and with which the student may be familiar. Such mimeographed notes, however, make a bulky and inconvenient reference book for later use.

4. What are the advantages and disadvantages of conducting a course in Mechanics by the use of some standard textbook?

Prof. G. P. Boomsliter.—Educators consider the text book—recitation method as stultifying. As originally practiced, it would be so, especially in a subject like Mechanics. But, must it be? Assum-

ing a teacher of some experience and background in practice, can he effectively use this method to advantage to the student? I think he can. He assigns as a lesson a few pages in a book and in the course of a semester "gnaws his way," as someone has said, through the book. But let us examine this process. Why is the lesson assigned? To familiarize the student with new principles and with some of their applications. Why ask questions in connection with the lesson? I think that only enough routine questions should be asked to insure that the lesson will be studied by each student every day so that on coming to class the instructor can feel that his class is already familiar with the subject to be discussed. Those who have had experience know that an occasional zero for lack of preparation will do this. Then, on this assumption, the teacher either through questions raised by the students or propounded by him starts a discussion of the reasonableness and application of the principles discussed in that lesson. He may on occasion take up without questions a definite application in the form of a problem, if it is broad enough or important enough from the standpoint of engineering application. Perhaps he can thus lead up to another application to be solved by the students themselves as a blackboard exercise. Again, another point of view than the author's may be discussed and the reasonableness or effectiveness of the two compared. Thus the recitation becomes not a stultifying procedure, but a means of providing for the recall of the work done at home, and for application to real engineering problems of the new ideas developed in the lesson. Many instructors not using text books undoubtedly have had students request that a text book be required so that important principles may be found in them after the lesson is over with little effort, and from this point of view an old text book may become an almost invaluable part of the engineer's library in later years.

Prof. J. E. Boyd.—A good text book saves the student's time and gives him clearly printed material for review and further reference. It may contain material which must be omitted from the college course for lack of time but may be profitably studied in after life by the engineer who needs it. One can study better from a text book with which he is fairly familiar than from some work which uses unfamiliar symbols and methods of treatment.

Prof. S. G. George.—The advantages are that this method is very convenient for the instructor and for the student. Different sections are quite certain to cover the same material, to keep abreast of each other, and to have the same good opportunities to study and review their work as the best of other plans of teaching Mechanics can offer.

The presentation is most likely to be well considered before such

a text is printed, and the form, sequence of topics, illustrations and legibility can hardly be bettered by any other method.

The disadvantages are that the course becomes crystallized, the problems stale or the solutions so commonly available that some students merely copy them with no personal effort applied to their work, and that the emphasis is laid upon topics that are not suited to the training of students for their later courses.

It is difficult to select a text that covers no more and no less than the work desired by the faculty. Other considerations have been more extensively discussed in connection with the other items in the seven topics assigned by the chairman of Committee No. 27.

Prof. C. E. Paul.—Answered under Item No. 3.

Prof. A. P. Poorman.—A textbook, if well written and if printed with good, open type and clear, well-made figures, is considered to be the best method of getting the necessary principles of the subject before the student. Such a text is usually better edited than mimeographed notes, but of course lacks their flexibility. It provides the student with a familiar reference book for his later work. It has the disadvantage that there is little opportunity for the student to add material of his own, although margins and the few blank pages may be so used.

5. In the light of your own teaching experience, what advice in regard to his undergraduate course would you give a student who intends to prepare to teach Mechanics?

Would you advise any post-graduate work in addition?

Any normal school work?

Any courses in psychology?

Prof. G. P. Boomsliter.—Post-graduate work is certainly of value in providing background and breadth of view. A sound course in the principles of teaching given by a teacher with his feet on the ground would undoubtedly add to the effectiveness of a teacher of Mechanics.

Prof. J. E. Boyd.—He should have taken some engineering courses which apply Mechanics. Some advanced courses in physics are desirable. Advanced mathematics should include differential equations. Should study some advanced texts in Mechanics, and have laboratory training in Mechanics and materials. A year or two of graduate work with a minimum of teaching is desirable. Practical experience of the right kind is rated high with us.

Prof. S. G. George.—The writer has personally known no students who, at the beginning of their course in engineering, had any idea of becoming teachers. Nor has any student presented such a career to the writer for consideration. If the writer may be permitted in the lack of personal contact, to make a few observations, he would state:

That a student proposing to teach Mechanics, or any other subject, for that matter, should make sure that he would enjoy doing that to doing any other possible thing;

That he has a natural gift at explaining a subject;

That he has a good voice, a fair or good command of English (or of the language he expects to use);

That he has a pleasing appearance, and no absurdities of manner;

That he has some administrative ability;

That he will learn much more about the subject than he ever expects to teach;

That he will observe critically the good and bad points in the teachers with whom he comes in contact throughout his course.

He should do some post-graduate work, preferably incidental to his first teaching.

He should NOT take any Normal School work in New York State.

He should consider carefully before taking any course in psychology, or in a professional department of education.

Prof. C. E. Paul.—I hardly know how to answer Item No. 5, as it has been my experience that most teachers of Mechanics are more likely to decide upon their line of work after graduation from college, than they are to fit themselves for such work during their period of college training. I believe that a student who is to teach Mechanics should have the ability to follow mathematical demonstrations easily, and to be ingenious in his use of theoretical mathematics and mechanics. Post-graduate work in Mechanics is extremely valuable if an instructor is to teach the lines outside of those ordinarily considered as "Applied Mechanics." Courses in psychology and education are of extreme value to any instructor.

Prof. A. P. Poorman.—So far as I recall, I have had only two students who came to me during their course in Mechanics and asked for advice relative to preparation to teach Mechanics. They were advised to take another year of undergraduate work, so as to obtain a degree in one of the other schools of engineering, chiefly for the purpose of familiarizing them with applications of the principles of Mechanics in other fields. If resources permitted, graduate work would be desirable, but preferably after one or two years of teaching.

The work of normal schools is along lines quite apart from engineering, so little advantage could be expected as a direct result of courses taken in such schools. Courses in Psychology and general education, if taught properly, should be of some value, but would not be considered absolutely necessary.

6. Should the young instructor in Mechanics be urged to take up some line of research?

Will research, in itself, add to the value of a teacher to his students?

Prof. G. P. Boomsliter.—Research, like post-graduate work, ought to aid in providing material with which to illustrate the application of principles. An illustration from one's experience is always more effective than one obtained from the writings of others. In the writer's experience the determining of stress deformations and stresses in a structure by means of a strain gage and the subsequent checking of such stresses by the laws of mechanics have often added interest and vividness to his class room presentations. But the research work must not be so engrossing as to drive from the teacher's mind serious thought concerning the effectiveness of his teaching.

Prof. J. E. Boyd.—Better begin with intensive study of some branch of the subject and repeat investigations already published by others. When his preparation is sufficient, he may profitably take up some original problem. Research should not interfere with his teaching, and publication should not be regarded as necessary for promotion. Good teaching should come first. Research and the right kind of practical experience have about equal value.

Prof. S. G. George.—To the first, the writer says "No", the urge should come from himself as his interest and need arise. Some of the poorest instructors the writer had as a student were those compelled by whatever pressure to immerse themselves in research.

To the second part, generally "No". Not many experts in research prove to be good teachers. Their tendency is to make a research problem of each student and of each class. While education may suggest a drawing-out process, the work should rather be interpreted as a leading on, and the research process results in getting nothing where there is real emptiness. It was said of Euler that IF many of the modern problems of engineering and of science had been presented to the operations of his powerful intellect, he could have solved them easily. Somehow, or by some one, the essential elements of even simple problems must be presented to students, or their powers of analysis will have nothing to build upon.

Prof. C. E. Paul.—I believe that every instructor in Mechanics should parallel his work with research and practical work in the line which he is following. I believe that the addition of such practical work makes him more human in his line of endeavor and gives him a standing in the eyes of his students which he cannot obtain in any other way. He is able to cite instance after instance in connection with the theory in which such work will aid the students later in their chosen line of endeavor. If he is active in the consulting field and in the various engineering societies, the publicity which will come to him through such activities will make him a conspicuous

figure both among his associates and his students. He is looked upon as a "live wire" in his line.

Prof. A. P. Poorman.—The urge for research should come from within. If the young instructor does not have that inward urge to work out some problem in original investigation, the results are likely to be mediocre and discouraging. The time and energy required in such research may better be applied to routine teaching work.

7. From the standpoint of good teaching, would it be advisable for a young instructor to alternate for a few years between teaching and practical work?

Prof. G. P. Boomsliter.—By all means let the teacher of mechanics get some practical experience before teaching. If this work is such as to enable him to spend his summer vacations practising his profession he will not only come back in the fall with a fresh enthusiasm but with a wealth of new illustrations for his class work.

Prof. J. E. Boyd.—Desirable if it can be arranged. Summer work is a partial substitute.

Prof. S. G. George.—This is advisable provided the work is of a nature to give a variety of problems and a certain experience. However, it is not usual to find such opportunities on a definite job. Perhaps some other procedure might be better; for instance, to visit several jobs and get a wider range of problems and supplement these with reading of engineering periodicals.

Prof. C. E. Paul.—See answer to Item No. 6.

Prof. A. P. Poorman.—Practical work for the teacher of Mechanics, or for the teacher of any other engineering subjects, for that matter, is eminently desirable. It gives first-hand information on the application of theory to practice which can be obtained no other way. Practical considerations, such as moving the family to another city and back again, accommodating them to the lower scale of living made necessary by the usually lower rate of pay for short time employment, and arranging for a suitable substitute during the time absent, often weigh heavily against such arrangements. Summer employment appears to be the most feasible means for the university teacher to obtain contact with practical work.

THE MISSISSIPPI RIVER FLOOD CONTROL*

BY ARTHUR E. MORGAN

President, Antioch College

The Mississippi is a very unstable river. As we see it today it is comparatively new. Before the glacial period the river which now flows between Missouri and Illinois was a relatively insignificant stream. It rose in northern Missouri or Iowa, and flowing south along what is now the east side of Missouri, turned to the west through southern Missouri and then south over the flat lands of Arkansas and Louisiana.

The Ohio River was not a part of the Mississippi until after the glacial period. The latter flowed into the Gulf in a channel of its own, along the present course of the lower Mississippi. The Red River of the south, rising in the west, flowed easterly through what is now Texas, Oklahoma, Arkansas, and Louisiana, and then south through Louisiana to the Gulf of Mexico, also a separate stream.

Up until very recently, the Black River, which is possibly the remains of the old Mississippi, flowed between the Red River and the present Mississippi and had its own way to the Gulf. The Mississippi, for the past few scores of thousands of years, has been in a process somewhat similar to that of our large New York and Chicago banks at present. It has been gathering in subsidiaries and making a larger institution.

When the glaciers had upset the topography further north, the Missouri River was forced out of its course to Hudson Bay. It turned south and joined the old Mississippi making a much more pretentious stream. Yet even then the Mississippi was small as compared with its present status.

Some time after the glacial period a branch of the Ohio River, cutting its way north through southern Missouri, inter-

* Presented at the 37th Annual Meeting of the Society, Ohio State University, June 19–22, 1929.

sected the Mississippi and united the two, and so, what was formerly the lower part of the stream we call the Ohio River, now is the main outlet of the Mississippi. Then, very recently, within the past few hundred years, the Red River and the Mississippi, running parallel to each other in their windings back and forth, happened to come together and united. So, the Red River joined the system of the Mississippi, leaving its old bed as a bayou.

Out of those four streams—the Missouri River—that formerly went north to Hudson Bay, the Ohio that went in a channel by itself, the Red River that came from the West and flowed south to the Gulf, and the Mississippi—which was a small stream between the Ohio and the Red—there gradually grew the great system we now know as the Mississippi River.

The Mississippi Delta, as it is called, that flat, alluvial plain extending from southern Missouri down to the Gulf of Mexico, also has been a very unstable region. It has had a habit of rising and falling. If we could have a slow moving picture of that region, with a shot taken every hundred years instead of every twentieth of a second, we would see that region alternately rising and falling perhaps 100 or 200 feet, somewhat rhythmically but unevenly.

In that long continued rising and settling there has been a great disturbance of the status and equilibrium of the river. In addition, in its own erosive action and in the deposit of silt and sand along its course, it has cut its banks back and forth from one side of its valley to the other.

During the glacial periods the amount of ice that was piled up on our polar areas was very great indeed, enough to lower the sea level possibly 200 feet. The lower portion of the Mississippi was adjusted to this lower sea level elevation. Then at the end of the glacial period when the water returned to the oceans, the ocean level rose perhaps 200 feet and drowned out the lower reaches of the Mississippi. We can imagine what a different stream the lower Mississippi would be if the ocean level should again drop 200 feet.

All of those factors have kept the Mississippi River System in turmoil. The lower river perhaps never has had a channel

adequate for its floods. In that respect the Mississippi is not peculiar, for many of our rivers are inadequate to the largest of their flood flows. Some are more inadequate than others.

The Mississippi River in low water has a discharge of less than 10 per cent of its maximum flood flow, and the river channel is in some rough degree adequately adjusted to the ordinary water stage. When the floods come they find a regimen that is not at all adjusted to them.

The normal condition of the Mississippi River, before white people came, was that during low water the channel wound back and forth through the country, carrying the flow within its banks. In moderate freshets the water was greatly disturbed in its crooked channel and it threw out sand and clay over the banks. It would cave off one bank and throw out that dirt a little farther downstream. In that way it built up a sort of ridge along its course. The immediate river bank would be perhaps five or six feet higher than the country a mile or two back. Then in the next mile there would be a slope of possibly two or three feet, and in the next mile possibly one or two feet.

In extreme cases the land along the Mississippi river front may be 30 feet or more higher than the land 20 or 30 miles back. To a considerable degree the river flows along a ridge of its own building. Near it the coarsest sand was quickly dropped by the overflow water, and so the river front soil generally is a sandy loam, easily tilled. Back from the river where the water was relatively quiet the fine clay was deposited, and the soil is sticky and harder to cultivate.

When the country was first settled, the planters in that region farmed the loose sandy soil along the river front. It was better drained and easier to cultivate. Back from the river a few miles were the almost impenetrable swamps.

The planters along the Mississippi river front would harvest many of their crops successfully, but every now and then a freshet would wipe out the corn and the cotton just when it was well started. The planters tried to protect themselves against those freshets. A planter would plow a furrow around the farm, or get his slaves to throw up a ridge along

the river front possibly three or four feet high to keep off the little freshets. In the openings between the farms the water would flow into the back country, as it always had done. That kind of simple protection lasted for a number of years. In years of highest water the planters lost their crops.

As the immediate front land was taken up the planters wanted to occupy more land, so they joined together the private levees and the community levees appeared, sometimes stretching for ten or twenty miles along the river, with only here and there a bayou which led the overflow water into the back country during flood time.

With the flood openings restricted, the river tended to rise somewhat higher and often broke over the protection that the planters had built. Quite a number of years ago the states began to pass laws giving these planters the right to organize levee districts and to tax themselves, and to compel cooperation for the building up of the levees. But the levees continued to follow the winding river front, being built a little higher and a little higher as the years passed.

As time went by the help of the United States Government was sought. No justification could be found, under our Constitution, for protecting private lands. But on the assumption that navigation would be helped by building these levees, the United States Government began to supervise the construction, to set grade lines running over long distances, and to advise with the local authorities as to how to build.

Then the United States Government began to protect the sharp bends where the banks would cut. In high water the mud and clay and sand banks of the river would cave rapidly. Sometimes a great bend in the river would be cut through, and then the levees would be destroyed and much land would be lost.

As a help to navigation the Federal Government began to take care of this bank protection. Then in comparatively recent years the Federal Government has undertaken to help with the actual construction of levees. For quite a number of years it paid a third of the cost, and the local organizations paid the other two thirds.

Something more than fifty years ago the Federal Government gave to the various states along the river several million acres of lowlands on the condition that these states would dispose of the lands and use the proceeds to help in the protection from floods.

Little by little the part which the Federal Government has played in the protection of the Mississippi River from floods has increased. Until recently the justification for levee building by the Government was held to be the value to navigation. Whether there is any definite effect upon navigation from levee construction, I shall not stop to discuss. The same plea, of helping navigation on the Mississippi, has been used in the establishment of national forests in the Alleghenies. In each case it was really an excuse for the undertaking, rather than the real reason.

From the time that the first planters began to throw up their little levees along the river, the building of levees has been recognized as the orthodox method of control of the Mississippi. Fifty years ago when the first Federal survey of any importance was made, the problem of the Mississippi was not very well understood. The size of floods that could pass down the river was not known. The topography of the water shed and the nature of the drainage area were not closely determined, and construction methods as we know them to-day had not been developed.

In 1874, a commission of engineers, chiefly Army engineers, examined the situation and made a report in which it stated that there was only one proper way to control the floods on the Mississippi, and that was by the construction of levees. This commission reported that the cost of total and complete protection against floods on the Mississippi would be about $46,000,000.

The Mississippi River Commission, again composed chiefly of Army engineers, was formed by Congress and put in charge of the Mississippi. Year by year the Commission has estimated the cost of complete protection. After having charge of the problem for about twenty years, the Chief of Engineers officially reported that complete protection from all floods

would cost $18,000,000. Up to the 1927 flood the cost had been about $300,000,000.

In the early days of Mississippi River control, there was a strong feeling among many civilian engineers that levees alone might not solve the problem; but the Army engineers and the Mississippi River Commission spoke with commanding authority, and quite effectively silenced the opposition. Until the flood of 1927, the program of "levees only" was held as the one orthodox doctrine of the Army engineers for Mississippi river control.

Even for the five years before the flood, the presidents and the members of the Mississippi River Commission, and the Army engineers who were associated with them and were responsible for that work, reported year by year that "levees only" was the right program for the Mississippi. Year by year they went over the various suggestions of other methods and dismissed each of them as having been fully disposed of and fully inquired into. Within a year or so of the 1927 flood the president of the Mississippi River Commission, repeating what his predecessors had said for years before, stated explicitly that "levees only" was the right policy for the Mississippi. He reiterated what had been the orthodox, authentic policy of the Army engineers and the Mississippi River Commission for a half century.

As the work progressed the Mississippi River Commission in its annual reports would state the degree of protection achieved. During the past fifteen years statements have appeared year by year that the Mississippi River was safe against any but the most extreme floods. Then for about three years before the 1927 flood, all reservations were removed and the statements appeared annually in the official annual reports of the Mississippi River Commission that the Mississippi River was now safe against all disastrous effects of floods. The job, in their opinion, was substantially complete.

Presidents of the Mississippi River Commission stated that there was no uncertainty as to the amount of money necessary to complete the job. They said that $70,000,000 would complete the work, and that there would be then no further need

for the existence of a Mississippi River Commission except to do work on the tributary streams.

From time to time various civilian engineers had suggested other methods of control of the Mississippi as being perhaps desirable. The River Commission and the Army engineers in charge of the river, in complete assurance of being right, had generally depreciated surveys and examinations and other inquiries for studying general methods of control as being useless. They held that the question was settled, and there was no uncertainty about it. They held that the expenditure of money for topographical surveys, for the study of reservoir possibilities, or for an hydraulics laboratory, would be wasted. That was the attitude of the Mississippi River Commission and the Army engineers up to the 1927 flood.

About a month before that flood the annual report of the Commission appeared in which the statement was repeated that the Mississippi was fully and completely safe from disaster due to floods, although there was still about $70,000,000 to be spent to provide a uniform factor of safety throughout the course of the river.

The 1927 flood was an interesting commentary upon those reports. In determining the manner of protecting the river from floods, the Mississippi River Commission had assumed that the greatest flood which could occur would be identical with the greatest recent flood; that is, exactly the same amount of water would come out of each tributary. They took the 1912 flood to be an exact type of a maximum flood, and the percentages which the Ohio River, the Missouri River, and the Red River delivered in that flood they considered as typical of the maximum flood. So the plans for levee construction were designed to be safe with a repetition of the 1912 flood. As the years went by, different floods were chosen for that standard, but always the greatest recent flood was the standard by which the levees were built.

The unsoundness of that position, of course, lies in this: that the particular distribution of water in any particular flood is a sheer accident; that a maximum flood may, at some time,

occur on several tributaries at once; and that this problem must be worked out on the theory of probabilities as to what a maximum flood would be. The short experience of 50 years is not enough to furnish a basis for estimating what a maximum flood may be on the Mississippi River.

The 1927 flood was of such dimensions that on some parts of the River the levees would have had to be ten feet higher than they actually were in order to be safe. The failure of the levee system was not due to any local cause. If it had not failed in one place, it would have failed somewhere else. The inadequacy of the entire levee system was complete. It was not that there was a weak spot here, or a levee there that had not been brought to a permanent grade. It was not any temporary or local ineffectiveness or incompleteness. Even if all the little deficiencies had been corrected and if the system as a whole had been fully completed to the standards of the Army engineers, the failure would have been approximately as great. The failure was an essential failure of the system as a whole. It has been reported by Army engineers that none of the recent levees built to standard did fail. That is only because breaks in the older and lower levees served as spillways. If they had been brought up to standard, the whole system would have failed just the same. It was wholly inadequate.

In February of 1927 the doctrine of the Mississippi River Commission and the Army engineers was as it had been for fifty years, "levees only." Between the time of the flood in the spring of 1927 and about five months later a revolution took place. A commission of army engineers was appointed to make a study. There are more than two million square miles of drainage area which was "investigated." Various groups of Army engineers, with a hurriedly assembled staff of civilian assistants, made hasty studies of various methods of protecting the river.

At a meeting of the American Society of Civil Engineers I was asked to discuss one method of protection, that is, protection by reservoirs, and I became interested in looking into the degree of preparation that was made by the Army engineers

for their report on the possibilities of reservoir control. I found that for actual field study over the Mississippi River drainage area approximately thirty days was allowed for engineers to gather in the significant data for the preparation of that report, about sixty days was allowed for field work including re-reference for reviews, and about two months more was allowed to sum up all of that matter.

In order to do the work quickly certain fundamental assumptions were given to the engineers who were to do the research work on reservoir sites. I think I can make the statement without qualification, that in the haste of making up these standards for study, or through a lack of knowledge of the principles involved, the assumptions that were given to the engineers for the control of those reservoirs was so fundamentally faulty that the resulting conclusions of necessity were entirely unreliable and misleading. I believe a report built upon those assumptions and upon that very hasty study is worse than no report, because it gave a feeling of satisfaction, a feeling of having looked into the situation, when, in my opinion, the situation never was adequately studied.

After fifty years of failure to make a comprehensive study of flood control methods, the effort to solve so great a problem in the course of a few months was more than any group of human beings could accomplish. The failure to make an adequate study in so short a time, I think, was innate in the situation. If there had been an open and candid admission that three or four years would be necessary to develop a plan, and that during that time only emergency measures should be executed, the situation would have been correctly presented. The public temper was demanding immediate protection, and an admission of half a century of misunderstanding of the problem was too much to expect.

Two plans for the control of the Mississippi were submitted to Congress in 1927 and 1928. The Mississippi River Commission made a report in which it estimated that it would cost about $700,000,000 to permanently control the Mississippi River floods. A commission of Army Engineers appointed by the Chief of Engineers of the Army made an in-

dependent and conflicting report, and in that report the finding was that a little less than half as much would be required. This great divergence of the two boards is an indication of the unreadiness to present an adequate plan.

These two reports, with a difference of more than 100 per cent in estimates of cost, went to Congress. Congress referred them to the Chief of Engineers who had been responsible for the smaller estimate, with instructions that he, together with two other men, one of them to be a civilian engineer, were to make up a commission to compose the differences. The Chief of Engineers of the Army and two of his former assistants were appointed to constitute the commission. The Chief of Engineers approved his own report without change, with its lower estimate of cost.

The American Society of Civil Engineers took an interest in this project from time to time. At its Denver meeting in 1928, the Board of Directors passed a resolution offering the Chief of Engineers the cooperation of the American Society of Civil Engineers through its president in reviewing the plans that were being made. The Chief of Engineers advised the president of the American Society that this was an Army problem and that the help of the Society was not desired.

At the next meeting of the American Society of Civil Engineers three months later, that request was repeated and was met by a like refusal. Three months later, just before the Flood Control Law was passed, the Board of Directors of the American Society of Civil Engineers unanimously reported to Congress and the President that they felt this plan was not adequate and should be reviewed. That resolution, we were told, came too late to receive consideration, because the bill was about to be passed.

Since then, the Executive Council of the United Engineering Societies has reported to the President that in its opinion the plan of the Mississippi River Flood Control should be thoroughly reviewed.

In my opinion, a plan for the protection of the Mississippi River that will be adequate for a long time to come has not

yet been prepared. A large amount of fundamental data must be collected, and a much more thorough study must be made of the situation than has been made up to the present.

I believe that a right policy for the present would be to determine, as quickly as possible, what elements of protection probably would be a necessary part of any plan that is adopted. There are certain elements of protection that would apply to any plan. Emergency expenditures should be confined to such elements, and then, before the nation is committed irretrievably to a line of action, there should be a far more fundamental study of the problem from every point of view, a study possibly occupying a few years. Out of that study there should grow a policy which takes into account every factor of the situation.

WHO'S WHO IN THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

The Council authorized the Secretary to send out blanks to each member of the Society, the information returned on them to be used in compiling a Who's Who in the Society for the Promotion of Engineering Education. These blanks have been distributed and some have been returned. We are desirious of securing this information from all members. If you have mislaid your blank, or have not received one, please write to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa., and he will send you one.

EXECUTIVE COMMITTEE ACTION

The Society has stocked with the Lancaster Press, Lancaster, Pa., and upon which we must pay storage and insurance, an excess of the following volumes of the *Proceedings:*

Volumes 1 to 15, inclusive,
17 to 29, inclusive,
31, 34, 35,
Volumes 16, 30, 32 out of print.

The Executive Committee has recommended that these volumes be offered for sale at 50 cents per volume in order to reduce the number in storage. This is an opportunity to complete your set at very little cost. Orders should be accompanied by checks and should be sent to the secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.

SUMMER SCHOOL FOR TEACHERS OF ENGINEERING DRAWING, 1930

Due to the generous cooperation of the Carnegie Institute of Technology, Pittsburgh, a session of the Summer School for Engineering Teachers will be held at that institution June 12–21, 1930, for teachers of engineering drawing. This will be conducted in close cooperation with the Executive Committee of the Drawing Division of the Society.

Director Wm. E. Mott, of the College of Engineering of the Carnegie Institute of Technology, will act as Director of the session. Professor Thomas E. French, of Ohio State University, will serve as Chairman of the teaching staff, Professor H. M. McCully, Head of the Department of Drawing, Carnegie Institute of Technology, will serve as Secretary of the session. Detailed plans for the program and other features of the session are now being prepared and will be published in the JOURNAL in the near future.

If experience with past sessions is any guide, there will be a surplus of applicants to attend the session. In general, applications are considered in order of receipt. Some have already been received. Others may be sent to H. P. Hammond, Director of the Summer School for Engineering Teachers, 99 Livingston Street, Brooklyn, N. Y.

NEW MEMBERS

ALBERT, ARTHUR L., Assistant Professor of Electrical Engineering, Oregon Agricultural College, Corvallis, Ore. R. E. Summers, L. F. Wooster.

ANTHONY, RICHARD L., Instructor in Mechanical Engineering, Yale University, New Haven, Conn. S. W. Dudley, W. J. Wohlenberg.

BALDWIN, ORVAL J., Instructor in Engineering Drawing, State University of Iowa, Iowa City, Iowa. R. M. Barnes, F. F. Mavis.

BRISTOL, FRANK J., Instructor in Electrical Engineering, Cornell University, Ithaca, N. Y. D. S. Kimball, W. C. Ballard, Jr.

BRUMFIELD, RAY C., Assistant Professor of Civil Engineering, Cooper Union, New York City. F. E. Foss, N. L. Towle.

COOLIDGE, WARREN A., Assistant Professor of Civil Engineering, Vanderbilt University, Nashville, Tenn. F. J. Lewis, W. H. Schuerman.

DAVIDSON, FREDERIC A., General Manager, Chesebro-Whitman Co., Inc., Long Island City, N. Y. R. I. Rees, F. L. Bishop.

DIXON, SOLON, Instructor in Mechanical Engineering, Alabama Polytechnic Institute, Auburn, Ala. J. C. McKinnon, Y. A. Elizondo.

FRIGON, AUGUSTIN, Director of Studies, Ecole Polytechnique, Montreal, Canada. H. M. MacKay, C. M. McKergow.

GERARDI, JASPER, Instructor in Drawing, University of Detroit, Detroit, Mich. D. P. Gilmore, R. E. Lawrence.

GODFREY, WILLIAM P., Instructor in English, University of Detroit, Detroit, Mich. D. P. Gilmore, R. E. Lawrence.

GRISMER, FRANK A., Instructor in English, University of Colorado, Boulder, Colo. W. Otto Birk, H. S. Evans.

HINCKLEY, ALFRED D., Instructor in Electrical Engineering, Columbia University, New York City. J. H. Morecroft, W. A. Curry.

HULL, ROBERT H., Assistant Professor of Electrical Engineering, University of Idaho, Moscow, Ida. I. C. Crawford, J. H. Johnson.

HURLBUTT, FREDERICK L., General Manager, The Patent Scaffolding Co., Chicago, Ill. R. I. Rees, F. L. Bishop.

JOHNSTON, CLAIR C., Assistant Professor of Civil Engineering, University of Detroit, Detroit, Mich. D. P. Gilmore, R. E. Lawrence.

KNIGHT, ABNER R., Assistant Professor of Electrical Engineering, University of Illinois, Urbana, Ill. H. H. Jordan, E. B. Paine.

LEE, MYRON A., Professor of Industrial Engineering, Cornell University, Ithaca, N. Y. W. N. Barnard, D. S. Kimball.

MAHONE, LESLIE W., Assistant Professor of Civil Engineering, Iowa State College, Ames, Iowa. R. A. Caughey, F. E. Klotz.

MAXWELL, H. L., Associate Professor of Chemical Engineering, Purdue University, Lafayette, Ind. A. A. Potter, J. E. Walters.

MURPHY, GLENN, Instructor in Civil Engineering, University of Colorado, Boulder, Colo. C. L. Eckel, H. S. Evans.

PITOU, EUGENE, President, The Patent Scaffolding Co., 522 Fifth Avenue, New York City. R. I. Rees, F. L. Bishop.

SERVISS, FREDERICK L., Associate Professor of Engineering Geology, Purdue University, Lafayette, Ind. A. A. Potter, J. E. Walters.

STEVENS, WILLIAM J., Instructor in Mechanical Engineering, Drexel Institute, Philadelphia, Pa. J. H. Billings, R. C. Disque.

STOCK, ORION L., Associate Professor of Architectural Engineering and Drawing, Rose Polytechnic Institute, Terre Haute, Ind. John B. Peddle, C. L. Mees.

THOMAN, WILLIAM H., Instructor in Civil Engineering, University of Colorado, Boulder, Colo. C. L. Eckel, H. J. Gilkey.

VAN DYKE, JAMES R., Assistant Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. B. Robertson, J. R. DuPriest.

WATWOOD, VERNON B., Assistant Professor of Civil Engineering, Alabama Polytechnic Institute, Auburn, Ala. J. J. Wilmore, J. A. Callen.

WILLIS, BENJAMIN S., Assistant Professor of Electrical Engineering, Iowa State College, Ames, Iowa. F. A. Fish, V. P. Hessler.

COLLEGE NOTES

Armour Institute of Technology.—The Institute announces Faculty promotions and new appointments as follows: Charles W. Leigh, B.S., Associate Professor of Mechanics; promoted to Professor of Analytical Mechanics. David P. Moreton, B.S., E.E., Associate Professor; promoted to Professor of Direct and Alternating Current Machinery. Benjamin B. Freud, Ph.D., Ch.E., Associate Professor of Physical Chemistry; promoted to Professor of Organic Chemistry. C. Austin Tibbals, Ph.D., Associate Professor; promoted to Professor of Analytical Chemistry. Daniel Roesch, B.S., M.E., Associate Professor; promoted to Professor of Automotive Engineering. James C. Peebles, B.S., E.E., M.M.E., Associate Professor; promoted to Professor of Experimental Engineering. Arthur F. Deam, B.A., F.A.A-R.; appointed Associate Professor of Architectural Design. Walter H. Seegrist, B.S., Instructor in Elementary Machine Drawing and Descriptive Geometry; promoted to Assistant Professor of Machine Design. Arthur W. Sear, B.S., Instructor; promoted to Assistant Professor of Machine Design. Herbert Ensz, B.S., appointed Assistant Professor of Civil Engineering. Eldon C. Grafton, B.S., appointed Assistant Professor of Structural Engineering. Walter L. Suter, B.S., appointed Instructor in Architectural Design. Jay E. Peterson, B.S., M.S., appointed Instructor in Architectural Design. Ferdinand T. Foerster, appointed Instructor in Forging. Carl H. Johnson, B.S., appointed Instructor in Fire Protection Engineering. Fletcher W. Pearce, B.S., appointed Instructor in Surveying. Theodore M. Hofmeester, Jr., appointed Instructor in Architectural Modeling. Dorothy Cornwell, appointed Assistant Librarian.

University of Colorado.—Mr. William Thoman has been transferred to the Civil Engineering Department from the faculty staff in Engineering Drawing. Mr. Glenn Murphy

replaces Mr. Phil Milstein as part-time instructor. Mr. L. Clifton Snively, formerly a Fellow in the Electrical Department, replaces Mr. Ross Middlemiss in Engineering Mathematics; and Mr. Jacob Britton, of Clark University, replaces Mr. E. F. Peterson. Mr. Oden S. Knight replaces Mr. Fred Van Doorninck in Mechanical Engineering; and Mr. George S. Dobbins replaces Mr. C. F. Garland, who is on leave. Mr. F. P. Gibbs, formerly in Physics, now replaces Mr. Thoman in Engineering Drawing.

University of Illinois.—Two professors on the Engineering staff at the University of Illinois were retired under the rules of the University on September 1, and are now professors, emeritus. They are: Professor Morgan Brooks, who has been a professor in the Department of Electrical Engineering at the University of Illinois since 1901, and Professor Albert Pruden Carman, who has been a professor in the Department of Physics since 1896, and head of the department since 1912. Professor Carman is spending this year in Europe.

Professor Francis Wheeler Loomis, formerly Associate Professor of Physics at New York University, has been appointed Professor of Physics and Head of the Department, succeeding Professor Carman. Professor Loomis graduated from Harvard University with the Bachelor of Arts degree in 1910, and received the Master of Science degree in 1913, the Doctor of Philosophy in 1917. He served as Instructor at Harvard University from 1913 to 1915. He was employed in the research laboratories of the Westinghouse Lamp Company in 1917 and again in 1919–20. From 1920 to 1922 he was Assistant Professor of Physics at New York University, and has been Associate Professor since 1922. During the World War he served as Captain of Ordnance. He is the author of a number of scientific treatises on Thermal Properties of Ammonia, Heat of Vaporization of Mercury, Theory of Iodine Fluorescence, etc. Last year, Professor Loomis studied in Europe as the holder of one of the Guggenheim Fellowships.

It is with deep regret that the College of Engineering records the sudden death of Professor G. A. Goodenough, one of its most distinguished faculty members, a professor who has brought prestige to the work of the College and particularly to the Department of Mechanical Engineering through his thirty-two years of teaching, research and administration services in the University of Illinois. A biographical sketch and an appreciation of Professor Goodenough was printed in the October issue of the JOURNAL.

Two members of the faculty are away from the University this year on leaves of absences. Professor H. M. Westergaard is on one-year leave with the U. S. Bureau of Reclamation, Department of the Interior, as a technical expert, making a complete mathematical analysis of the Boulder Canyon Dam. Professor H. E. Babbitt is on sabbatical leave and is making a tour of inspection of sanitary systems in various parts of the world. Leaving San Francisco late in the summer, he went to Hawaii, thence to the Philippines, and then to Tokyo where he will attend the World Engineering Congress. From Japan he will go to China, Siam, Australia, India, Egypt, returning to Urbana through Europe.

Dr. A. N. Talbot, Professor of Municipal and Sanitary Engineering, Emeritus, is the only other member of the staff besides Professor Babbitt, who is attending the World Engineering Congress in Tokyo, Japan. Professor Talbot sailed from San Francisco on October 10, and he will leave Tokyo, November 26.

The academic year 1929–30 marks the opening of the new Materials Testing Laboratory. Begun in June, 1928, furnished and partially equipped during the summer of 1929, it was ready for use when school opened in September, 1929.

The new building will house the laboratories of the departments of Civil Engineering and Theoretical and Applied Mechanics, which include the following: structural, highway, cement and concrete, applied mechanics, fatigue of metals, and hydraulics. In addition there are five class rooms and rooms for special researches.

A feature of the building is a crane bay having a clear space 40 feet wide, 147 feet long, served by a 10-ton crane, 50 feet above the floor. A part of the floor of the crane bay, 108 feet long by 24 feet wide, is concrete 16 inches thick, and has anchors spaced 6 feet apart each way, each capable to taking an upward pull of 50,000 pounds.

An outstanding feature of the equipment of the new laboratory is the 3,000,000-lb. Emery-Tatnall testing machine now under construction by the Southwark Foundry and Machine Company. This machine will take tension or compression specimens 35 feet long.

In the Hydraulics Laboratory the new equipment includes a centrifugal pump, having a capacity of 14,000 gallons per minute against a thirty foot head. There are also five smaller motor-driven pumps of capacities ranging from 500 to 2,000 gallons per minute.

The registration in the College of Engineering for 1929–30 on October 1, was 1,758, showing an increase of 61 over the registration on October 1 of last year.

SECTIONS AND BRANCHES

The **Colorado Branch** met informally, on October 17, in the main engineering building for their annual Fall Reception. This social gathering is probably one of the most enjoyable of the year. Many of the faculty are new; many have been serving on the faculties of other colleges, or have spent the summer in large factories; many have been away on vacation trips; all have interesting news to relate.

While the grown-ups were busy meeting the new members and old friends, "Uncle" John Hunter, Professor of Mechanical Engineering, entertained the children with a movie.

The chairman of the committee was Professor C. A. Hutchinson.

BOOK REVIEW

Elementary Mechanics. J. B. REYNOLDS. Prentice-Hall, Inc., N. Y. Pp. 250.

In this text the author has set out to present the usual topics of statics, kinematics and kinetics in an elementary manner for students who have not yet taken work in calculus. The treatment is clear, logical and in many instances, very ingenious.

Necessarily many subjects are omitted or treated in a very sketchy manner. It is a difficult matter to handle such questions as center of gravity and moment of inertia without the use of calculus. The author, however, has given very satisfactory elementary methods for finding these properties of simple figures and combinations.

The field of statics is treated with sufficient completeness for most of the needs of engineering students. Kinematics is limited to straight line and circular motion with constant acceleration, simple harmonic motion and the parabola. The work in kinetics covers the same range.

Many instructive illustrative problems are solved in the text, and under each topic is given a full and well chosen list of problems.

The book may be highly recommended for a beginning course, and in conjunction with the authors "Analytical Mechanics" should give the student an excellent training in this important subject.

J. A. D.